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UNIFIED FACILITIES CRITERIA (UFC)

RAILROAD DESIGN AND REHABILITATION

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RAILROAD DESIGN AND REHABILITATION

Indicate the Military Department Preparing Activity responsible for the document.

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

This UFC supersedes UFC 4-860-01FA, dated January 2004.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

AUTHORIZED BY:

PETE G. PEREZ, P.E., SES
Chief, Engineering and Construction
U.S. Army Corps of Engineers

R. DAVID CURFMAN, P.E., SES
Chief Engineer
Naval Facilities Engineering Systems Command

NANCY J. BALKUS, P.E., SES
Deputy Director of Civil Engineers
DCS/Logistics, Engineering &
Force Protection (HAF/A4C)
HQ United States Air Force

MICHAEL McANDREW, SES
Deputy Assistant Secretary of Defense
(Construction)
Office of the Secretary of Defense

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

This Unified Facilities Criteria (UFC), UFC 4-860-01, provides requirements for designing and rehabilitating railroad track, terminal and loading facilities. The requirements contained in this UFC apply to Army, Navy, and Air Force facilities unless specifically referenced to a single service. This UFC is not intended as a substitution for thorough review during design by individual Program Managers, Engineers and Operations Staff in the appropriate service.

The desired goal of this UFC is to maintain consistency in railroad tracks, terminals and loading facilities requirements across the Army, Navy and Air Force. This UFC is not intended as an operational manual.

1-2 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 4-860-01FA, *Railroad Design and Rehabilitation*, dated 16 January 2004.

1-3 PURPOSE AND SCOPE.

This UFC provides technical requirements to design and rehabilitate railroad track, terminals, and loading facilities, along with information on construction. This UFC is for railroad lines operated at speeds and traffic volumes lower than common in the commercial industry. The technical requirements on terminal design are for small terminals handling military cargo: primarily tracked or wheeled vehicles and intermodal containers.

This UFC, supplemented with the specified references, provides information for general purposes. Most projects, however, include aspects that are site-specific or uncommon conditions. Designers are encouraged to obtain assistance when encountering unusual or unfamiliar situations.

1-4 APPLICABILITY.

These instructions are applicable to all DoD elements and their contractors involved with railroad design, construction, and rehabilitation.

1-4.1 Applying the Material in this Manual.

Designing a railroad often involves satisfying conflicting objectives. Throughout the process, the designer must prioritize project objectives and decide what objective to sacrifice to satisfy another. Properly balancing these compromises, tailored to each situation, produces an effective railroad design.

1-4.2 New Lines and Terminals.

To design new railroad lines and terminals, utilize Chapters 2 through 3 and 5 through 7 of this instruction. The design process summary is as follows:

a. Determine the traffic and load carrying requirements. Estimate the number of cars to be processed over the line and magnitude of the wheel loads the track must support.

b. Determine the terminal and support facilities requirements. From the type and magnitude of traffic, determine the number, size, location of loading and unloading facilities (terminals), sidings, wyes, and other support facilities and auxiliary tracks.

c. Establish route profile and alignment guidelines. Based on load carrying requirements, maximum desired speed, locomotive pulling capability, and other operating needs and conditions, select maximum effective grade, horizontal and vertical curvature, and other profile and alignment specifications.

d. Select the route. Through an iterative process, select the best route and profile between the terminals and the connecting commercial railroad, usually the nearest commercial railroad line. Include considerations of climate change on flood resiliency in accordance with the installation master plan and UFC 2-100-01 Installation Master Planning.

e. Design the track, roadway, and terminal and support facilities. From the traffic and wheel load estimates and the characteristics of the selected route, determine track, roadway, and drainage requirements.

1-4.3 Rehabilitation.

For rehabilitating existing lines and facilities, refer to Chapters 4 through 7, along with portions of Chapter 2.

1-5 USING THE AREMA MANUAL FOR RAILWAY ENGINEERING.

The American Railway Engineering and Maintenance-of-Way Association’s Manual for Railway Engineering (AREMA) is a standard industry reference and is cited throughout this technical manual. It contains a wide range of guidance with emphasis on commercial lines carrying substantial freight traffic. As a broad range of specifications is often given, proper use of the AREMA manual requires that the designer select the particular specifications most appropriate for a particular project.

The AREMA manual is written primarily for the commercial railroads that have their own company policies and procedures. The material assumes that many details are unnecessary, as a company’s own practices will govern. Therefore, military designers require details in addition to the material contained in the AREMA manual. In addition, requirements for operating on military railroads differ from those commonly found on commercial railroads. In these cases, the design guidance in this technical manual can vary from that found in the AREMA manual. For these reasons, when preparing designs and specifications, avoid general statements, such as, “meeting AREMA specifications”. Such statements often leave the choice of materials or procedures wide open and lead to an undesirable or unsatisfactory product. When designing, clearly specify the work task and the acceptable construction materials.

1-6 OVERARCHING CRITERIA OR REGULATORY REQUIREMENTS.

Ensure designs meet all applicable state and local standards for new construction or rehabilitation. Design standards are typically obtained from the appropriate state departments of transportation or public utilities.

In addition, ensure that any new or rehabilitated track regularly utilized by a commercial railroad complies with that organization’s track requirements. Often commercial railroads require review and approval of the proposed design by their engineering department before operating over the proposed track.

1-7 SOURCES OF ASSISTANCE.

Designers are encouraged to seek assistance when questions arise on the best choice to suit a particular situation or for further interpretation of material in this manual or another reference. Obtain assistance through the Army Transportation Systems Center, Omaha, NE (CENWO-ED-TX) or Air Force AFCEC/COSC.

Installations that depend on a commercial railroad service for routine traffic or during a mobilization, contact the owning commercial organization and at a minimum coordinate the arrangement of the interchange yard and other track configurations to facilitate more convenient service.

1-8 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-9 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

1-10 GLOSSARY.

APPENDIX D contains a list of acronyms, abbreviations, and definitions.

1-11 REFERENCES.

APPENDIX E contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 DETERMINING TRAFFIC AND LOAD CARRYING REQUIREMENTS

2-1 INTRODUCTION.

The first step in designing a railroad is determining the type and volume of traffic. Traffic type and volume generally govern the size and arrangement of terminal facilities, the number of auxiliary tracks required, and track structure design. Ensure the traffic handling capability at an installation covers existing and foreseeable requirements to include:

- Mobilization outloading.
- Training exercises.
- Installation supply (routine traffic).

Once assembled, review and approve data on traffic volume and type before proceeding with the design process.

2-2 TRAFFIC TYPE.

Information gathered on traffic type includes:

a. Type of cargo processed.

b. Type and size of freight cars.

c. Manner of cargo loading and unloading.

d. Height and width of cargo (for clearance requirements) carried on open cars (flatcars and gondolas).

e. Special requirements or restrictions for loading, unloading, or moving the cargo, especially hazardous cargo.

f. Determine the required type of loading facilities from this information. Chapter 7 covers planning and design for loading facilities. Table 2-1 lists the most common cargo types along with the freight cars and loading facilities to handle the cargo. Figure 2-1 shows common freight car types.

2-3 TRAFFIC VOLUME.

Estimate the amount of traffic using:

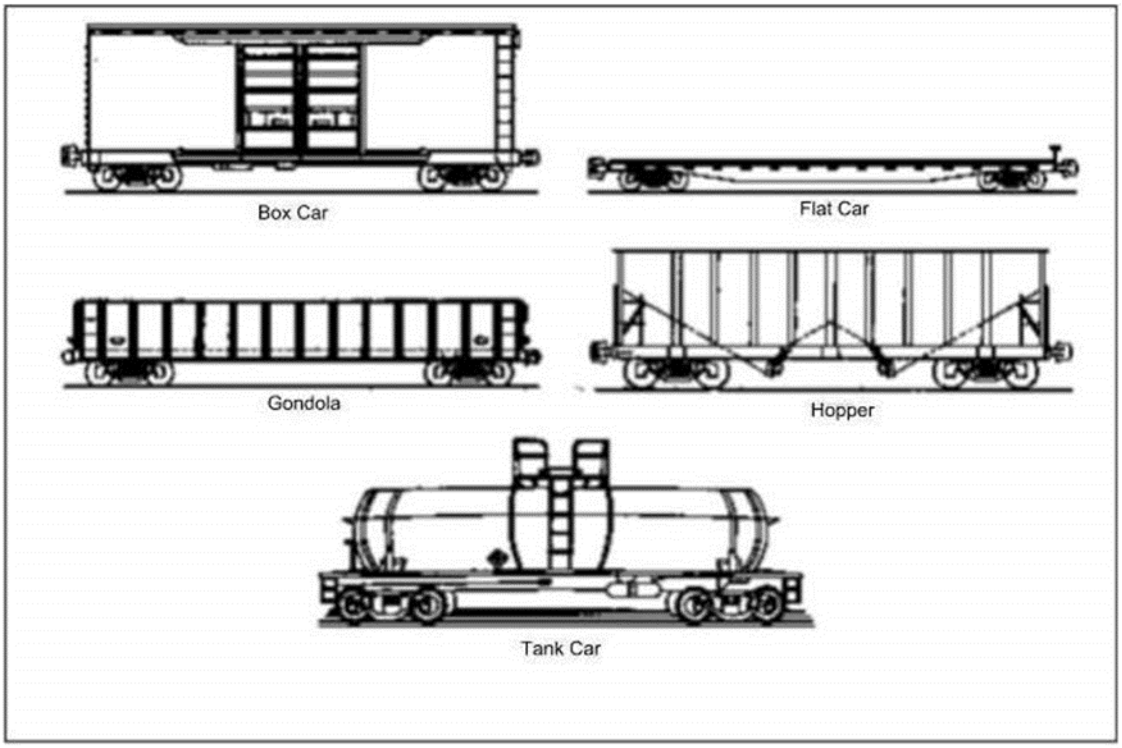
a. Maximum number of cars for each traffic type on the installation at any one time, including empty cars.

b. Longest train to accommodate into or out of the installation.

Table 2-1 Common Cargo Type and Loading Requirements

CARGO	CAR TYPE	LOADING/UNLOADING METHOD	FACILITY REQUIRED
Light wheel 0.25 – 2.5 T (0.23 – 2.27 MT)	Auto racks Bi/Tri-levels	Circus-type loading/unloading - staging area and bridge plates are required	Multi-level end ramp
Heavy wheel 5.0 T – HET (4.5 MT – HET)	Flatcar 40 – 140 T (36.3 – 127 MT)	Circus-type loading/unloading - staging area and bridge plates are required.	Permanent/portable end ramp
Light track (APC, Bradley)	Flatcar 40 – 140 T (36.3 – 127 MT)	Circus-type loading/unloading - staging area and bridge plates are required.	Permanent end ramp
Heavy track (Tank: M1, M60)	Flatcar 140 T (127 MT)	Circus-type loading/unloading - staging area and bridge plates are required.	Permanent end ramp
Engineer equipment (Wheel & track)	Flatcar 40 – 140 T (36.3 – 127 MT)	Special load items - crane access next to track may be required. Bridge plates are needed.	Permanent end ramp
40 ft (12.1 m) Container	COFC	Crane w/spreader bar or Rough Terrain Container Handler (RTCH) and yard tractor /trailer tandems.	Container loading facility
20 ft (6 m) Container	COFC	Crane w/spreader bar or RTCH and yard tractor /trailer tandems.	Container loading facility
Conex	Flatcar Gondola	Crane loading/unloading - crane access required next to track.	None
POL (bulk)	Tankcar	Pumping or dumping through a pipe network.	POL handling facility equipped with spill containment
POL (palletized)	Boxcar	Forklift into warehouse or dock, staging area next to dock may be required.	Side loading ramp equipped with spill containment
POL (containerized)	COFC	Crane w/spreader bar or RTCH and yard tractor /trailer tandems.	Container loading facility equipped with spill containment
Ammunition (palletized)	Boxcar	Forklift onto dock, staging area needed next to dock.	Side loading ramp that meets the quantity-distance requirements
Ammunition (containerized)	COFC	Crane w/spreader bar or RTCH and yard tractor /trailer tandems.	Container loading facility that meets quantity-distance requirements
Miscellaneous breakbulk	Boxcar	Forklift onto dock, staging area needed next to dock.	Side loading ramps

Figure 2-1 Common Freight Cars



c. Maximum number of cars of all types on the installation at any one time, including empty cars.

d. Maximum number of cars that each loading facility or terminal area must process in a single loading or unloading cycle.

2-4 WHEEL LOADS.

The magnitude of wheel loads greatly influences track structure design. While many types of cars and loadings may service an installation, for planning purposes, design for the wheel load of the heaviest type of loaded car that commonly travels a particular track. In many cases, engine wheel loads (Army-owned or commercial railroad) represent the heaviest single load on the track. However, the number of wheels of loaded cars typically far exceed the number of locomotive wheels over much of the track. Therefore, the magnitude of the car wheel load governs in most cases. Check both loading conditions before final design.

Obtain the design wheel load by taking the static wheel load for the heaviest commonly used car and add a factor to account for the dynamic effects of travel speed combined with track and wheel irregularities. Table 2-2 lists suggested design wheel loads for planning purposes. To use the table, select the car type in the first column that most closely matches the heaviest car in common use over the track. For terminal areas and around an installation, where speeds are usually limited to 10 mph (16 km/hr), select the design wheel load in the column labeled “<= 10 mph (16 km/hr).” For track connecting the installation with the commercial railroad where train speed exceeds 10 mph (16 km/hr), use the column labeled “10-25 mph (16-40.2 km/hr).” For track mostly used by an engine during switching, or where mostly empty cars are stored, or otherwise see only occasional use, select from the column labeled “Light Use.”

2-5 LOCOMOTIVE TRACTIVE EFFORT.

2-5.1 Definition.

When designing a railroad route, it is necessary to know the pulling force a locomotive can exert. This pulling force is known as tractive effort. Tractive effort is maximum at starting and diminishes as speed increases.

2-5.2 Application.

Locomotive tractive effort, along with the route gradient and curvature, largely determines the maximum number of cars pulled over the route in a single train. Alternatively, locomotive tractive effort and minimum desired train size can determine the maximum acceptable grade and curvature on a route.

2-5.3 Tractive Effort Data.

Tractive effort data or graphs are often available for both military and commercial locomotives. When not readily obtainable, estimate the data from the locomotive weight and engine horsepower ratings. See Chapter 3, Paragraph 5.

2-6 TRAFFIC AND TERMINALS.

Once the traffic handling requirements are identified, as described in Chapter 2, Paragraphs 1 to 3, start the process of designing the terminal and support facilities. Determine the number and size (or length) of the required facilities and serving trackage from these traffic requirements. Chapter 7 covers planning and design for terminals.

2-7 SOURCES FOR TRAFFIC INFORMATION.

Obtain information about traffic types, car types, and volume, and mobilization requirements from the Installation Transportation Officer (ITO) and from the installation Transportation System Capability Study prepared by the Transportation Engineering Agency of the Military Traffic Management Command (MTTE-SEF).

Table 2-2 Common Car Types and Design Wheel Loads

Most Common Heavy Car	Design Wheel Load		
	10-25 mph (16-40.2 km/hr)	<= 10 mph (16 km/hr)	Light Use
Box, 40T	20,000 lb	17,600 lb	16,000 lb
Box, 50T	26,250 lb	23,100 lb	21,000 lb
Box, 70T	34,375 lb	30,250 lb	27,500 lb
Flat, 40T	17,500 lb	15,400 lb	14,000 lb
Flat, 50T	23,750 lb	20,900 lb	19,000 lb
Flat, 80T (6-axle)	23,750 lb	20,900 lb	19,000 lb
Flat, 100T (6-axle)	32,500 lb	28,600 lb	26,000 lb
Flat, 140T (6-axle)	38,750 lb	34,100 lb	31,000 lb
COFC, 70T	30,000 lb	26,400 lb	24,000 lb
COFC-Double Stack	50,000 lb	44,000 lb	40,000 lb
TOFC, 70T	30,000 lb	26,400 lb	24,000 lb
Gondola, 40T High Side	18,750 lb	16,500 lb	15,000 lb
Gondola, 50T	22,500 lb	19,800 lb	18,000 lb
Tank, 7500 gallon	16,250 lb	14,300 lb	13,000 lb
Tank, 10,000 gallon	22,500 lb	19,800 lb	18,000 lb
Tank, 20,000 gallon	36,250 lb	31,900 lb	29,000 lb
Hopper, 50T	21,250 lb	18,700 lb	17,000 lb
Hopper, 70T	30,000 lb	26,400 lb	24,000 lb
Hopper, 100T (263 K)	41,125 lb	36,190 lb	32,900 lb
Hopper, 120T (286 K)	44,750 lb	39,380 lb	35,800 lb
Hopper, 125T (315 K)	49,250 lb	43,340 lb	39,400 lb
Locomotive, EMD GP-7 or 9	37,500 lb	33,000 lb	30,000 lb
Locomotive, EMD SW-8	31,250 lb	27,500 lb	25,000 lb
Locomotive, DAV-BES 80T	25,000 lb	22,000 lb	20,000 lb
Locomotive, GE 65T	20,000 lb	17,600 lb	16,000 lb
Locomotive, GE 40T	13,750 lb	12,100 lb	11,000 lb
Locomotive, GE 25T	31,250 lb	27,500 lb	25,000 lb
Locomotive, NRE 3GS21B	41,375 lb	36,410 lb	33,100 lb

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CHAPTER 3 ESTABLISHING ROUTE PROFILE AND ALIGNMENT

3-1 INTRODUCTION.

Use the procedures in this Chapter (along with information on locomotive propulsion force, desired train capacity, propulsion resistances, and train operating requirements) to select the maximum grade and curvature and minimum transitions between grades and reverse curves.

Use these specifications as guidelines as construction costs vary depending on topography and other geological factors. Typically, the information and procedures described in this Chapter are used iteratively with those in Appendix A until a suitable solution is reached. Appendix B gives a sample problem illustrating the determination of a ruling grade. The specifications listed in this chapter are primarily for main running tracks. Chapter 7 gives additional profile and alignment specifications for terminal areas. Paragraphs 2 and 3 of Chapter 5 detail layout of horizontal and vertical curves.

3-2 GRADES AND GRADE RESISTANCE.

3-2.1 Definition.

Railroad grades are designated by the amount of elevation change in 100 ft (30.5 m) of length, expressed in percent. The additional force required to move a train, due to the presence of a grade, is known as grade resistance. Grade resistance equals 20 lb. per ton of train weight per percent grade. Thus, it takes twice the force to pull a train up a 2-percent grade as it does a 1-percent grade to overcome grade resistance. For this reason, the choice of maximum gradient greatly effects route operations.

3-2.2 Ruling Grade.

When a particular grade limits train size (tonnage) and speed over a route, that grade is known as the ruling grade. The ruling grade is not always the steepest grade, as a train’s momentum can carry it over a grade steeper, but shorter, than the ruling grade.

3-2.3 Grade Design Categories.

Table 3-1 lists grade design categories for main running tracks.

Table 3-1 Grade Design Categories for Main Running Tracks

Grade	Description
0.0 to 0.4 %	Light
0.4 to 1.0 %	Moderate
1.0 to 2.0 %	Steep
1.5 %	Suggested Limit for Ruling Grades
2.0 to 3.0 %	Very Steep: Approval required by the AHJ

3-3 ROUTE PROFILE AND TRANSITIONS BETWEEN GRADES.

3-3.1 Profile and Grade Length.

A route's profile is characterized by the steepness of grades and changes in grade along the route. Train operations are enhanced by avoiding frequent changes between ascending and descending grades (a rolling profile). Simplify route design and construction by avoiding frequent changes in grade steepness. Table 3-2 shows recommended minimum grade lengths.

Table 3-2 Recommended Minimum Grade Lengths

Maximum Speed	Between Different Ascending or Descending Grades	Between Ascending and Descending Grades
15 MPH (24.1 km/hr) or Less	500 Feet (152.4 m)	1000 Feet (304.8 m)
Above 15 MPH (24.1 km/hr)	1000 Feet (304.8 m)	1500 Feet (457.2 m)

3-3.2 Transitions between Grades.

Transitions between grades are made with vertical curves. These transitions are necessary for smooth train operation, but they increase the amount of surveying and staking required and are more difficult to construct than uniform grades.

Design guidance for grade transitions is given in Paragraph 2.2 of Chapter 5.

3-4 CURVATURE, CURVE RESISTANCE, AND EFFECTIVE GRADE.

3-4.1 Minimizing Curvature.

In general, sharper curves require more maintenance than gradual curves; they experience more rail side wear and gage widening. They also create more propulsion resistance. Minimizing curvature in a route provides long term benefits.

3-4.2 Curve Design Categories.

Table 3-3 shows curve design categories for main running tracks and terminal tracks.

Table 3-3 Curve Design Categories

Main Running Tracks	
Degree of Curve	**Design Category**
0 - 3	Gradual
3 - 6	Moderate
4	Preferred limit, especially where speeds will exceed 15 MPH (24.1 km/hr)
6 - 8	Sharp
8	Maximum allowable where speeds may exceed 10 MPH (16 km/hr)
10	Maximum allowable where speeds will not exceed 10 MPH (16 km/hr)
Terminal Tracks	
Degree of Curve	**Design Category**
10	Preferred limit, especially for lead tracks and where number 9 or 10 turnouts are the smallest recommended turnout size per Chapter 6
12	Maximum allowable

See Chapter 5, Paragraph 3 for additional horizontal curve design information.

3-4.3 Combining Curves.

When designing a route, accomplish changes in direction uniformly. Avoid a series of curves connected by short tangents. Where the distance between adjacent curves of the same direction is less than 300 ft (91.4 m), try to combine the two curves into one long curve of smaller degree (see Figure 3-1). Combining closely spaced curves usually provides advantages of less design work, easier construction, and reduced long-term track maintenance.

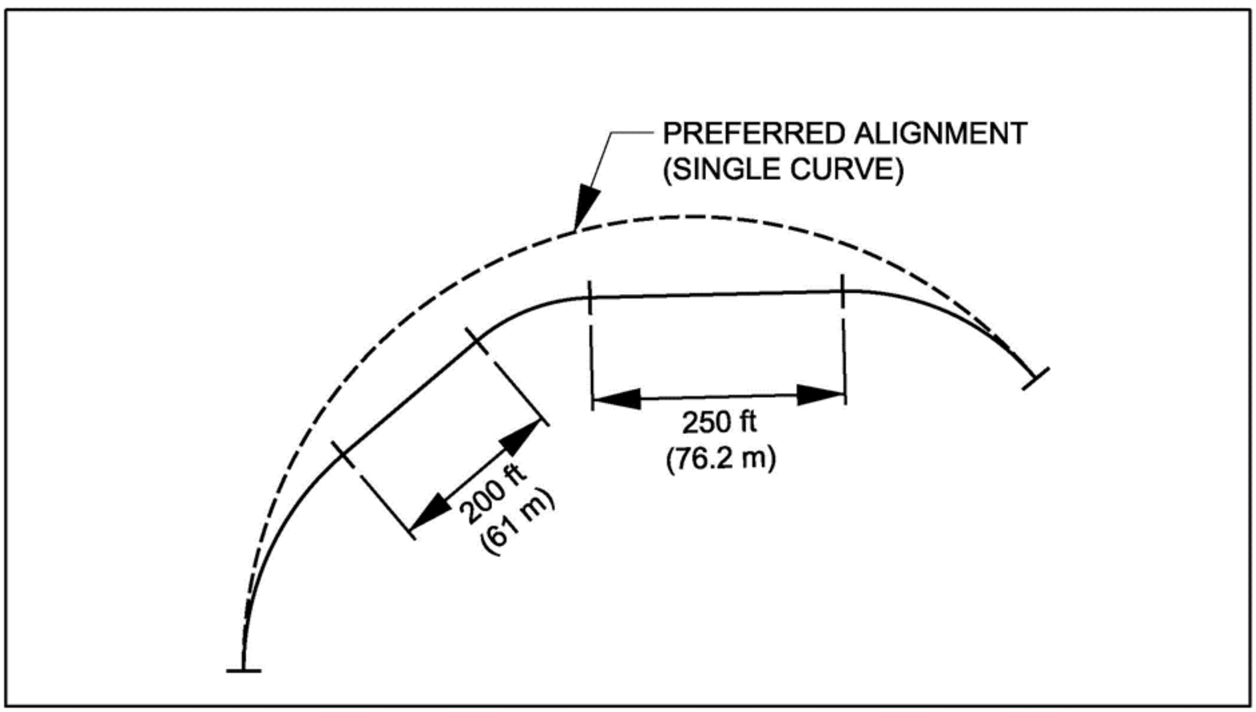
3-4.4 Curve Resistance.

Curvature adds to propulsion resistance at an average rate of 0.8 lb for each ton (.4 kg for each Metric ton) of train weight for each degree of curve. As a 1-percent grade adds resistance of 20 lb per ton (10 kg per Metric ton), a 1- degree curve is then equivalent in resistance to a 0.04-percent grade.

3-4.5 Curve Compensation.

When laying out a route, account for the additional resistance due to curvature. This procedure is known as curve compensation. Compensating a grade for curvature is almost always required for ruling grades and is recommended for grades in moderate and higher categories. Curve compensation is sometimes omitted where curves are very short or of gradual degree.

Figure 3-1 Combining Curves



When calculating curve compensation, reduce grades on curved track by the following:

Equation 3-1. Grade Reduction

$$G_r = 0.04 \times D$$

Where:
G_r = Amount of grade reduction (percent)
D = Degree of curvature (decimal degrees)

3-4.6 Actual and Effective Grade.

Table 3-4 illustrates curve compensation for a 1-percent grade. As shown, if a train travels around a long curve of 4 degrees on a 1-percent grade (uncompensated), the combined resistance is equal to a 1.16 percent grade. To maintain an effective grade (as experienced by the train) of 1-percent, the actual grade constructed through the 4-degree curve must be limited to 0.84-percent. Since the actual grade is reduced, compensating for curvature requires a longer track length to reach a given elevation.

Table 3-4 Curve Compensation for a 1 Percent Grade

Degree of Curve	Uncompensated Grade		Compensated Grade	
	Actual	Effective	Actual	Effective
1	1.00	1.04	0.96	1.00
2	1.00	1.08	0.92	1.00
3	1.00	1.12	0.88	1.00
4	1.00	1.16	0.84	1.00
5	1.00	1.20	0.80	1.00
6	1.00	1.24	0.76	1.00

3-5 LOCOMOTIVE TONNAGE RATING.

3-5.1 Definition.

The maximum train weight a locomotive can pull over a route is known as its tonnage rating. Tonnage ratings are affected by many factors, but locomotive tractive effort and ruling gradient are among the most important.

3-5.2 Application of the Procedures.

The procedures for estimating locomotive tractive effort and tonnage ratings presented below are simplified versions intended for route design purposes. Do not use these procedures to make-up and dispatch actual trains.

3-5.3 Tonnage Requirements, Locomotive Assignments, and their Effect on Route Design.

Design the route to allow trains of sufficient size to travel over the finished line. Determine the maximum train size from usable locomotive tractive effort and the gradients and curvature along the line. When designing, verify tonnage requirements with the appropriate transportation officers, as well as understand the general operating plan for routine traffic, training exercises, and mobilization.

On military railroads using government owned and operated engines, these engines might handle all routine traffic, but during training exercises or mobilization, a commercial engine can handle over-the-road operations, while the installation's engine takes care of switching and short moves. Alternatively, when installations have more than one engine, two engines can be used for maximum tonnage trains. Thus, in addition to tonnage requirements, also understand the local standard practice of locomotive use.

3-5.4 Determining Locomotive Tractive Effort.

3-5.4.1 Locomotive Capability.

Base tonnage ratings on curves when tractive effort curves are available for the locomotives. Otherwise, use expressions in Table 3-5 for tractive effort.

Table 3-5 Estimating Locomotive Tractive Effort

Speed Range	Tractive Effort
Starting to 10 MPH (16 km/hr)	TE = 30 x HP
Over 10 MPH (16 km/hr)	TE = 300 x HP / V
TE = Tractive Effort (in pounds) HP = Locomotive Rated Engine Horsepower V = Traveling Speed (MPH)	

3-5.4.2 Adhesion Limit.

Regardless of locomotive power, wheel rail adhesion limits the usable tractive effort. For design purposes, do not exceed W/4 usable locomotive tractive effort, where W is the weight of the locomotive in pounds.

3-5.5 Determining Tonnage Rating.

While tonnage ratings are commonly given in gross trailing tons (total weight of cars and loads), a convenient practice is to express tonnage ratings as the number of loaded cars a locomotive can pull, using an average or representative car and load for estimating purposes. Use Equation 3-2, along with Table 3-6 for selecting design car gross weight based on the nominal car carrying capacity. The constants 3 and 20 in Equation 3-2 indicate that an average car has a rolling resistance of 3 lb (1.4 kg) for each ton of its gross weight and that all equipment requires 20 lb (9.1 kg) to lift each ton of weight up each percent of grade. Any curvature on the maximum grade is assumed to be grade compensated, as described in Paragraph 4 of Chapter 3.

Equation 3-2. Design Gross Car Weights

$$\boldsymbol{N_{cars}} = \frac{\boldsymbol{TE}}{[\mathbf{3} + (\mathbf{20} \times \%\boldsymbol{G})]\boldsymbol{W_g}}$$

Where:
N_{cars} = Number of cars locomotive can pull
TE = Usable locomotive tractive effort at desired speed (lb)
%G = Maximum ascending gradient long enough to contain the whole train (percent)
W_g = Gross weight of representative car (tons), from Table 3-6

Table 3-6 Design Gross Car Weights

Nominal Car Capacity Tons (MT)	70 (63.5)	80 (72.6)	90 (81.6)	100 (90.7)	120 (109)	140 (127)
Design Gross Weight Tons (MT)	105 (95.2)	115 (104)	125 (113)	135 (122)	160 (145)	190 (172)
Note: 140-ton (127 MT) cars (nominal capacity) are representative of those carrying 2 M1 Tanks.						

For field check, car capacity is normally stenciled on the side of each car in pounds. Capacity is labeled as CAPY on each car. For example, the marking on a 70-ton car would appear as: CAPY 140000.

3-6 TRIAL RULING GRADE.

Determine a trial percentage for the ruling grade for the first stages of route selection using Equation 3-3. The 0.15 constant in the equation indicates that the average rolling resistance for each car is equivalent to pulling the car up an additional 0.15-percent grade.

Equation 3-3. Trial Percentage for the Ruling Grade

$$\boldsymbol{G = \frac{TE}{20(W_{eng} + N_{cars} \times W_g)} - 0.15}$$

Where:
G = Effective ruling gradient (percent), where the grade length is equal or greater than train length
TE = Usable locomotive tractive effort (pounds)
W_{eng} *= Weight of Engine(s) (tons)*
N_{cars} *= Number of cars in train*
W_g *= Average gross weight of a car (tons)*

As described in Paragraph 4 of Chapter 3, grade compensate all curvatures within the limits of the ruling grade. A ruling grade that is steeper, but shorter, than the calculated ruling grade can be used if the total train resistance of the cars on the grade and the cars off the grade does not exceed usable locomotive tractive force.

CHAPTER 4 REHABILITATION: TRACK, BRIDGES, AND TERMINALS

4-1 DEFINITION AND APPLICATION.

As used here, “rehabilitation” refers to work that falls between routine maintenance and new construction. It is often categorized as repair, minor construction, or a combination of the two. Rehabilitation involves restoring facilities to a “like new” condition and/or upgrading existing facilities to current design standards or installation requirements.

During the planning process, first establish current and future installation requirements. If subsequent investigations and analyses show that existing facilities can meet installation requirements through improving their condition and/or minor modifications, then rehabilitation is an appropriate option. Consider rehabilitation when:

- Routine track inspections reveal multiple defects that require speed restrictions or taking a track out of service.
- The track is not maintained or is out of service for an extended period.
- The track sustained multiple derailments.
- The condition of the track jeopardizes the facility’s mission.

4-2 INSTALLATION REQUIREMENTS AND FACILITY EVALUATION.

Review installation traffic and load carrying requirements, as described in Chapter 2. Then, crosscheck structural and operational requirements according to the criteria in Chapters 5, 6, and 7. Evaluations determines whether the track and facilities meet installation (mission) requirements, and if not, how they are deficient. Make these determinations through condition, structural, and operational evaluations.

4-3 CONDITION EVALUATION.

4-3.1 Level of Detail Required.

Condition evaluations occur in three stages or levels, depending on the size and scope of the project.

4-3.1.1 First Stage.

At the first stage, make a quick condition assessment based on recent inspection reports and inventory data and conduct a brief field survey. This assessment establishes the general rehabilitation requirements.

4-3.1.2 Second Stage.

The second stage is an evaluation for developing a rehabilitation plan. This information requires sufficient detail to determine the work needed at each location and to develop cost estimates for planning and budgeting purposes.

4-3.1.3 Third Stage.

At the third level, determine the exact work requirements, quantities, and locations for final contract plans and specifications.

4-3.2 Track.

Evaluate track condition based on the criteria given in UFC 4-860-03 and other major rehabilitation requirements. In addition, estimate major deficiencies expected within the next 3 to 5 years if rehabilitation is not performed. If the installation has more than five miles of track, consider using automated hi-rail track geometry testing to measure track gage, the horizontal curvature of the track, cross-level, and warp. The hi-rail geometry testing can measure approximately 15 miles of track per day, which would take several days to measure using manual, hand-held equipment. The hi-rail equipment uses GPS to track the location of the inspection results. This produces reports and interactive computer maps of the results that aid in preparing rehabilitation plans. Perform tie inspections, joint inspections, and turnout inspections using manual methods when utilizing hi-rail track geometry testing. Record current track deficiencies on a field report form.

Before completing the rehabilitation plan, perform an internal rail inspection if one has not been performed within the last 5 years. Thoroughly inspect all turnouts in the track intended for rehabilitation, including operation of the points. Figure 4-1 shows an example of the type of turnout inspection information commonly collected. Use other available forms, designed for routine maintenance requirements, if convenient.

4-3.3 Bridges.

Include a condition assessment of bridges on any line to be rehabilitated. This assessment can come from the last annual inspection, if that inspection is less than 6 months old. Otherwise, conduct a new condition assessment.

If a triennial inspection is due within 6 months for any bridge on a line to be rehabilitated, conduct the triennial inspection and load rating per Chapter 4, Paragraph 4 as part of the rehabilitation plan. If the last annual inspection indicates any significant change in condition of a main bridge member since the previous load rating, thoroughly inspect and load rate at least the included span or spans of the bridge per Chapter 4, Paragraph 4 as part of the rehabilitation plan.

4-3.4 Terminal and Support Facilities.

Evaluate the condition of all terminal and support facilities. Report this evaluation separately from the track evaluation.

Figure 4-1 Example Turnout Inspection Information

TURNOUT INSPECTION CHECKLIST

INSTALLATION	REPORTING ORGANIZATION	INSPECTOR (PRINT OR TYPE/SIGNATURE)
TRACK IDENTIFICATION	TURNOUT IDENTIFICATION	DATE

GENERAL

Are All Materials Proper Type?	YES	NO		NOTE ___
Is Rail Same Weight and Section?	YES	NO		NOTE ___
Are Flangeways Clear of Debris?	YES	NO		NOTE ___
Are Crib Areas Clear of Debris?	YES	NO		NOTE ___
Surface and Alinement:	GOOD	FAIR	POOR	NOTE ___

TIES

Total Number Defective:	___		NOTE ___
Maximum Number of Consecutive Defective:	___		NOTE ___
Number of Occurrences of Defective Joint Ties:	___		NOTE ___
Is Average Tie Spacing LESS THAN 22 Inches?	YES	NO	NOTE ___

FROG

Point:	OK	WORN	CHIPPED	BROKEN	NOTE ___
Top Surface:	OK	WORN	BROKEN	DAMAGED	NOTE ___
Bolts:	OK	___ LOOSE	___ DAMAGED	___ MISSING	NOTE ___
Guarding Face (Self-guarded Frog Only):	OK	WORN	BROKEN	DAMAGED	NOTE ___

GUARD RAILS

Position - Straight	OK	IMPROPER	NOTE ___		
Turnout	OK	IMPROPER	NOTE ___		
Condition - Straight	OK	INSECURE	BROKEN	DAMAGED	NOTE ___
Turnout	OK	INSECURE	BROKEN	DAMAGED	NOTE ___
Fillers - Straight	OK	LOOSE	BROKEN	DAMAGED	NOTE ___
Turnout	OK	LOOSE	BROKEN	DAMAGED	NOTE ___
Bolts - Straight	OK	___ LOOSE	___ DAMAGED	___ MISSING	NOTE ___
Turnout	OK	___ LOOSE	___ DAMAGED	___ MISSING	NOTE ___

SWITCH AND STAND

Switch Operates Without Difficulty?			YES		NO (DESCRIBE PROBLEM)			NOTE ___
Switch Stand:		OK	INSECURE	DAMAGED	NOTE ___			
Point Lock/Lever Latches:		OK	MISSING	DAMAGED	NOTE ___			
Point Gap - Left:	NONE	LESS THAN 1/8"		1/8" OR GREATER	1/4" OR GREATER			NOTE ___
- Right:	NONE	LESS THAN 1/8"		1/8" OR GREATER	1/4" OR GREATER			NOTE ___
Point Condition - Left:		OK	WORN	CHIPPED	BROKEN			NOTE ___
- Right:		OK	WORN	CHIPPED	BROKEN			NOTE ___
Is Point LOWER Than Stock Rail?		Left:	YES	NO	Right:	YES	NO	NOTE ___
Is Point Rail Beyond Taper HIGHER Than Stock Rail?		Left:	YES	NO	Right:	YES	NO	NOTE ___
Connecting Rod:		OK	BENT	DAMAGED	LOOSE	BINDING		NOTE ___
Jam Nut:		OK		DAMAGED	LOOSE	MISSING		NOTE ___
Switch Rods:		OK	___ BENT	___ DAMAGED	___ LOOSE	___ BINDING		NOTE ___
Switch Clips:		OK	___ BENT	___ DAMAGED	___ LOOSE	___ BINDING		NOTE ___
Connecting Rod Bolt:		OK	___ LOOSE	___ DAMAGED	___ MISSING			NOTE ___
Nut On Top?		YES	NO	Cotter Key In Place?	YES	NO		
Switch Rod Bolts:		OK	___ LOOSE	___ DAMAGED	___ MISSING			NOTE ___
Nut On Top?		YES	NO	Cotter Keys In Place?	YES	NO		
Slide Plates:		OK	___ LOOSE	___ DAMAGED	___ MISSING	___ DIRTY		NOTE ___
Rail Braces - Straight Side:		OK	___ LOOSE	___ DAMAGED	___ MISSING			NOTE ___
Turnout Side:		OK	___ LOOSE	___ DAMAGED	___ MISSING			NOTE ___
Heel Filler (If Present):		OK	INSECURE	CRACKED	BROKEN			NOTE ___
Heel Bolts:		OK	___ LOOSE	___ DAMAGED	___ MISSING			NOTE ___
Heel Joint Bars/Shoulder Bars:		OK	___ LOOSE	___ CRACKED	___ BROKEN			NOTE ___

NOTES: ___

MEASUREMENTS (Inches)

	Straight Side	Turnout Side
SWITCH:		
Gage Just Ahead of Points:	___	
CURVED CLOSURE RAILS:		
Gage At Joints:		___
		___
FROG:		
Gage at Point:	___	___
Flangeway Width:	___	___
Flangeway Depth:	___	___
GUARD RAILS:		
Guard Check Gage:	___	___
Guard Face Gage:	___	___
Flangeway Width:	___	___

NOTES: ___

4-4 STRUCTURAL EVALUATION.

Perform a structural evaluation for all track, bridges, loading ramps, and other structures needed for railroad and terminal operations to determine current load carrying capacity. Use the computer program described in Chapter 5, Paragraph 6.1 for track structural evaluations.

4-4.1 Bridges.

The design capacity and present condition of the bridges along the route can determine the load-carrying capability of a railroad line. Have a practicing railroad bridge engineer examine and rate all bridges not thoroughly inspected and load rated within the previous three years. Conduct the rating in accordance with the AREMA manual for timber, concrete, and steel bridges.

Most military railroad bridges are of conventional timber design, built to an E60 rating. If these bridges are in very good condition, this capacity suffices for typical military traffic levels, including 140-ton (127 MT) heavy equipment flatcars. According to the AREMA rating guidelines, the in-service rating for bridges in very good condition can exceed their design rating. Additional material on bridge design ratings is found in Chapter 6, Paragraph 2.

4-5 OPERATIONAL EVALUATION.

Perform an operation evaluation on track and facilities to determine general suitability for mission requirements. Begin the evaluation with a check of track and facility capabilities along with basic geometric requirements, including:

- Number of loading and service tracks and usable car capacity of each.
- Car capacity of storage, yard, and auxiliary tracks.
- Clearances.
- Loading ramp height, width, and ramp slope.
- Size of parking and staging areas.
- Size of storage buildings in terminal areas.
- Track geometry.
- Maximum track curvature.
- Minimum turnout size.
- Protection and visibility at road crossings.

For terminals, evaluate the adequacy of lighting, service roads, and security features. For all track and facilities, check the adequacy of drainage. Include previous derailment sites and chronic problem areas in the evaluation.

4-6 THE REHABILITATION PLAN.

4-6.1 Purpose and Content.

The rehabilitation plan justifies the need for the recommended work. Document in the plan a thorough analysis of the existing facilities along with a clear presentation of mission requirements. The plan includes:

- Statement of installation (mission) requirements.
- Description of track and facilities and their current condition.
- Statement of deficiencies, based on condition, structural, and operational evaluations.
- A work plan of remedial actions to correct deficiencies, including an explanation of why the proposed actions were chosen over other alternatives.
- Cost estimates for each item in the work plan. Each of these items is discussed below. Appendix C contains an example track rehabilitation report; a similar format would also be used for bridges and terminal and support facilities. Appendix C presents realistic rehabilitation requirements and illustrates how track rehabilitation is commonly done. Use the plan as a guide in preparing track rehabilitation plans, particularly the sequential description of work.

4-6.2 Mission Requirements.

These are the current and expected future needs for regular traffic, training exercises, and mobilization, including amount and type of cargo, number and type of railroad cars to be handled, and terminal and support facilities requirements.

4-6.3 Description of Track, Bridges, and Facilities.

This includes a written description of facilities and their condition, along with track maps and photographs. If not previously done, assign a unique number or other designation to each track, bridge, and turnout. Mark each track with standard surveyor's stationing to help determine work and material quantities (from track lengths) and work locations, and to provide permanent reference location marks for future track inspections. In general, start track stationing with 0+00 at the point of the switch where the track branches from the main track, or for a main track, at the point where government ownership begins - at the connection with the serving commercial railroad.

4-6.4 Deficiencies List and Analysis.

Included in this section is a description of the major deficiencies found and an explanation of how these conditions interfere with, or prevent, the facilities from effectively supporting the required mission. As part of this explanation, compare the existing facilities to recommended design criteria. Include photographs to document deficiencies.

4-6.5 Work Plan.

The work plan lists recommended remedial actions for correcting deficiencies, along with the intended work limits. Within the work plan, clarify why these actions were chosen, and their advantages and benefits over other alternatives. For example, when a structural analysis indicates the need for a heavier rail section, eliminating the lighter rail often allows the installation to standardize with only one or two rail sections, thus requiring storing fewer sections for maintenance requirements and perhaps eliminating a section for which joint bars or additional pieces of rail are hard to find.

If the rehabilitation plan serves as the final plan and contract specifications, include all details of work in the work plan. Where appropriate, identify elimination of unneeded track, the possibility of re-using track materials elsewhere within the installation where traffic and structural requirements are lower, and the cost-effective sale, transfer (to another installation), or disposal of scrap and salvageable materials. For rehabilitation, re-gage the track if the existing gage is less than 56-1/4 in. (1.429 m) or greater than 57 in. (1.448 m).

4-6.6 Cost Estimates.

For plans for major rehabilitation, base cost estimates by pricing the major work items, with extra allowances for minor work at other locations and additional minor work within the major work locations or work categories. When the rehabilitation plan is done in one stage, the cost estimates must also serve for the contract plans and specifications. In this case, provide a more detailed cost estimate breakdown.

4-7 FINAL PLANS AND SPECIFICATIONS.

4-7.1 Detailed Work Plan.

Clearly define all work for the final contract plans and specifications. If not previously done, conduct a thorough inspection of all included facilities to assure correctness of work requirements, work locations, and work and material quantities.

4-7.2 Marking Parts for Replacement.

Individually mark all ties, rail, joint bars, bridge members, and other components intended for replacement and the limits for all work locations. When marking defective parts, especially ties, bridge members, switch points, and frogs, ensure those items in marginal condition (less than 3 to 5 years additional life) are included and marked for replacement.

4-7.3 Top-of-Rail Profiles.

When adding ballast to the track, and raising the track by 3 in. or more, take top-of-rail profiles (elevations along the top of the rail at 50 to 200-ft (15.2 to 61 m) intervals) to verify the final surface more easily. These profiles help in estimating ballast quantities. This is especially useful for poor existing track surfaces, as low areas require adjustment more than average to restore a smooth final surface.

Initial top-of-rail profiles are useful for track along loading docks to ensure proper car floor height at the dock. Take top-of-rail profiles wherever overhead clearances are tight.

4-7.4 Drainage Profiles and Cross Sections.

Before making final plans and estimates, take ditch profiles and cross sections to determine final ditch gradients and check earthwork quantities. Use these profiles to specify the exact work necessary and to guide the contractor’s work in the field.

4-7.5 Handling Scrap and Salvage Materials.

Ensure rehabilitation contracts and specifications require neatly stacking and/or bundling scrap rail and other track materials in a designated storage area for later disposal. Also include, separating salvageable rail and other track material (OTM) by type and weight, stacking or containerizing, and storage in a designated area for reuse by the installation or shipment to another installation.

If the contractor retains scrap materials, the government receives a cost credit for that amount of scrap. This cost credit equals the fair scrap value less a small amount for handling and transporting the material.

4-8 CONSTRUCTION AND ON-SITE INSPECTION.

Quality on-site inspections, during all remedial work, are essential for successful track rehabilitation. While inspection is no substitute for competently performed track work, it assures that all work is performed according with contract specifications. On-site inspection during rehabilitation work can reveal deficiencies or errors that are difficult to detect during a completion inspection, or expensive to correct if discovered after completion. Such items include:

a. Was all excess vegetation removed before ballast was unloaded?

b. For completely rebuilt track in crossings, was the old ballast completely stripped? Was the subgrade properly graded? Was drainage fabric installed? Were all new ties installed?

c. Did the track actually receive a full 3-in. (76 mm) raise (or were the rough spots just smoothed out)?

d. Was every tie tamped? Did each tie get two insertions by the tamper? Did joint ties (on the joint side only) get a third insertion? Likewise, correcting the following items after the work is done is difficult:

    - Tie and ballast material not as specified in the contract.
    - Old, fouled ballast in shoulders not fully plowed out before new ballast unloaded.
    - Culvert improperly positioned, or site not graded properly before culvert was installed.

- Defective concrete or insufficient reinforcing in loading ramp.

Use the same people that prepared the design and specifications to inspect the work.

CHAPTER 5 TRACK AND ROADWAY DESIGN

5-1 ROADWAY.

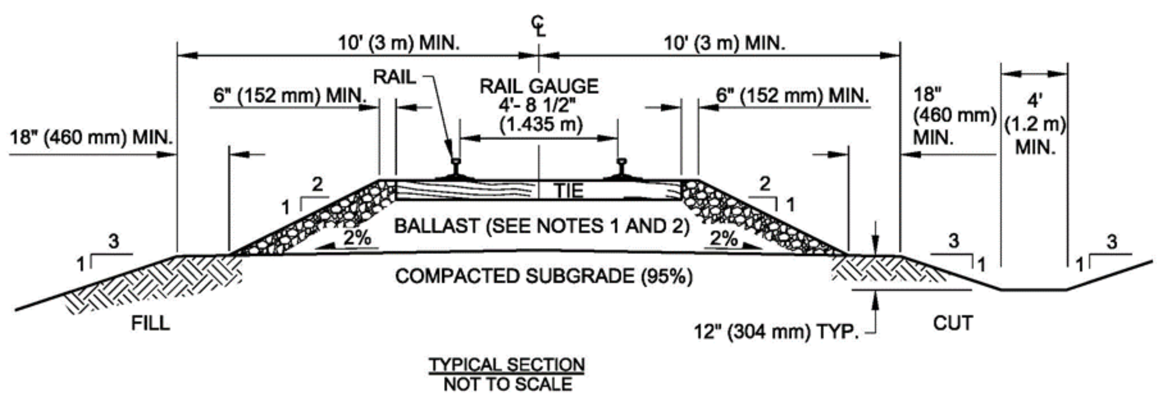
5-1.1 Definition.

The roadway is the strip of land containing the track, ditches, and other facilities needed for the operation of the railroad.

5-1.2 Roadway Width.

Roadway widths are wide enough to accommodate the track, side ditches, portions of embankment or cut slopes, parallel service roads, and other structures and facilities necessary for the operation of the railroad. The roadway must also allow sufficient clearances between the track and adjacent structures, as covered in Chapter 5, Paragraph 4. Figures 5-1 through 5-7 indicate the width required for the basic track structure. The roadway width must also meet the minimum requirements of the serving railroad, whichever is greater.

Figure 5-1 Typical Cross Section – Tangent Track



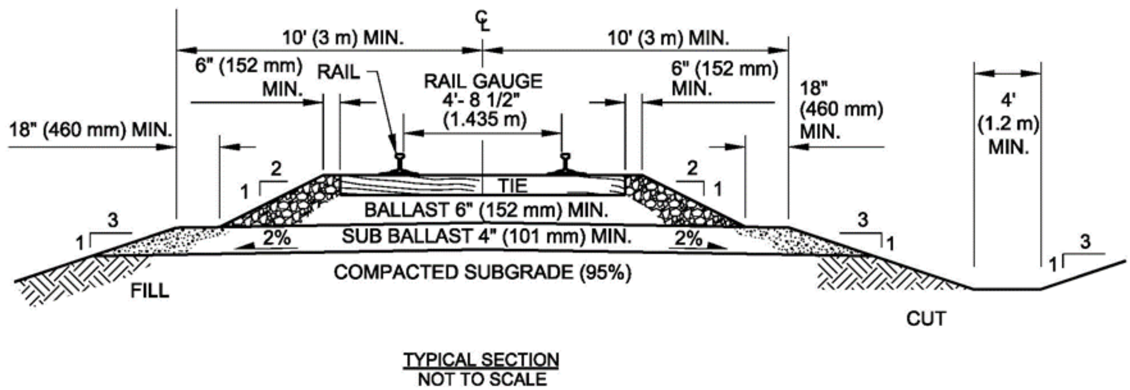
NOTES:

1. DEPTH OF BALLAST WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.

2. MINIMUM BALLAST THICKNESS IS 8 INCHES (203 MM) BELOW BOTTOM OF TIE.

3. CUT OR FILL ACCORDING TO LOCAL CONDITIONS.

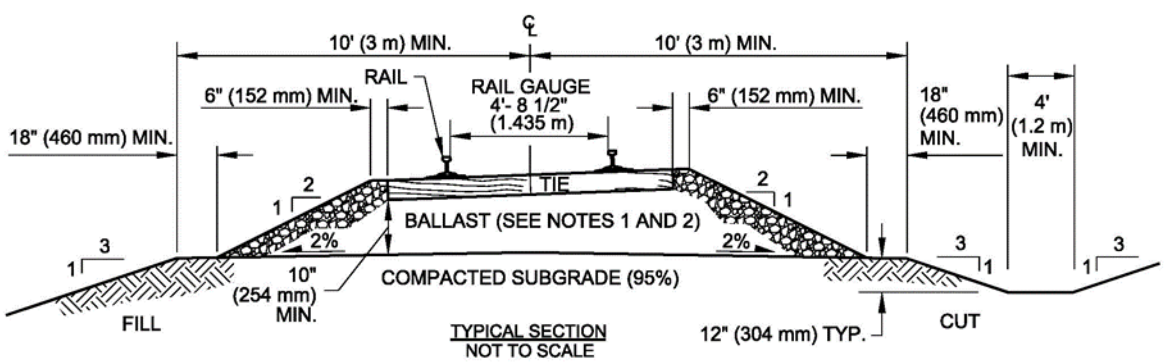
Figure 5-2 Typical Cross Section with Sub-Ballast Layer – Tangent Track



NOTES:

1. DEPTH OF BALLAST SECTION WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.
2. MINIMUM BALLAST/SUB BALLAST THICKNESS IS 10 INCHES (254 MM) BELOW BOTTOM OF TIE.
3. THICKNESS OF BALLAST AND SUB BALLAST MAY BE VARIED TO OBTAIN BEST STRUCTURAL AND ECONOMIC DESIGN WHILE MEETING MINIMUM THICKNESS REQUIREMENTS.
4. CUT OR FILL ACCORDING TO LOCAL CONDITIONS.

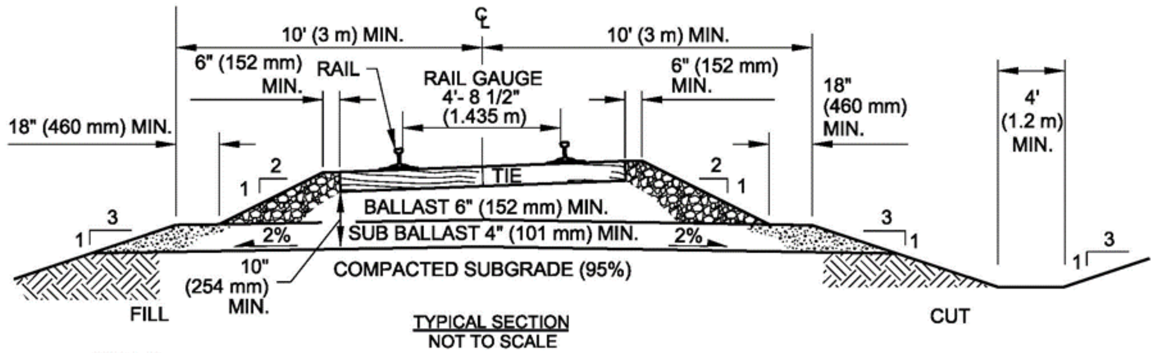
Figure 5-3 Typical Cross Section – Curved Track



NOTES:

1. DEPTH OF BALLAST WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.
2. MINIMUM BALLAST THICKNESS IS 8 INCHES (203 MM) BELOW BOTTOM OF TIE AT THE INSIDE RAIL OF THE CURVE.
3. ON CURVES OF 6 DEGREEA OR GREATER, USE A BALLAST SHOULDER WIDTH OF 8 INCHES (203 MM).
4. CUT OR FILL ACCORDING TO LOCAL CONDITIONS.

Figure 5-4 Typical Cross Section with Sub-Ballast Layer – Curved Track



NOTES:

1. DEPTH OF BALLAST SECTION WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.

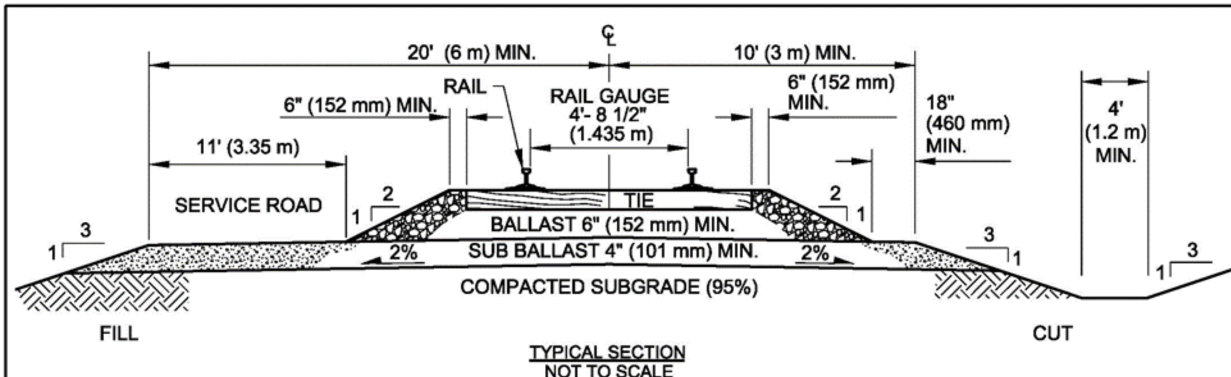
2. MINIMUM BALLAST/SUB BALLAST THICKNESS IS 10 INCHES (254 MM) BELOW BOTTOM OF TIE.

3. THICKNESS OF BALLAST AND SUB BALLAST MAY BE VARIED TO OBTAIN BEST STRUCTURAL AND ECONOMIC DESIGN WHILE MEETING MINIMUM THICKNESS REQUIREMENTS.

4. ON CURVES OF 6 DEGREEA OR GREATER, USE A BALLAST SHOULDER WIDTH OF 8 INCHES (203 MM).

5. CUT OR FILL ACCORDING TO LOCAL CONDITIONS.

Figure 5-5 Typical Cross Section – Track with Adjacent Service Road



NOTES:

1. DEPTH OF BALLAST SECTION WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.

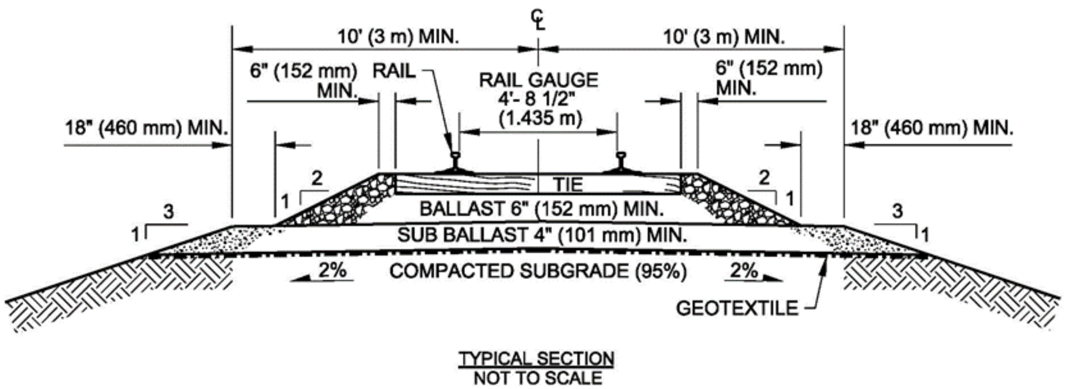
2. MINIMUM BALLAST/SUB BALLAST THICKNESS IS 10 INCHES (254 MM) BELOW BOTTOM OF TIE.

3. TO BE USED ONLY WHERE A SERVICE ROAD IS REQUIRED. SERVICE ROAD TURN AROUND REQUIRED EVERY 2,000 FEET.

4. SUB BALLAST WILL BE A MINIMUM OF 4 INCHES (101 MM) DEEP.

5. CUT OR FILL ACCORDING TO LOCAL CONDITIONS.

Figure 5-6 Typical Cross Section with Sub-Ballast Layer and Geotextile



NOTES:

1. DEPTH OF BALLAST SECTION WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS. USE RECOMMENDED STRUCTURAL ANALYSIS TO DETERMINE APPROPRIATE DEPTH FOR EACH SITE.

2. MINIMUM BALLAST/SUB BALLAST THICKNESS IS 10 INCHES (254 MM) BELOW BOTTOM OF TIE AT THE INSIDE RAIL OF THE CURVE WITH AREMA SIZE 5; 12 INCHES (304 MM) MINIMUM DEPTH WITH AREMA SIZE 4 AND 4A.

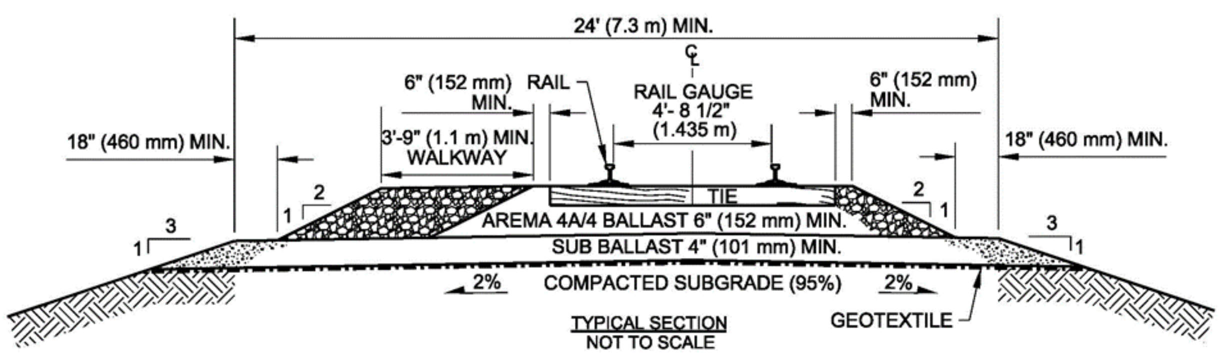
3. THICKNESS OF BALLAST AND SUB BALLAST MAY BE VARIED TO OBTAIN BEST STRUCTURAL AND ECONOMIC DESIGN WHILE MEETING MINIMUM THICKNESS REQUIREMENTS.

5-1.3 Walkways.

Walkways are required around turnout switch stands and next to tracks where personnel regularly walk to inspect railroad cars or access railroad cars to load and/or secure equipment. Walkways require additional roadway width. Walkways are not required where a service road parallels the track.

To facilitate easier walking, construct walkways of smaller-sized ballast than is used for the main track section. AREMA Size 5 ballast is typically used for walkways. A typical cross session showing a track with a walkway is shown in Figure 5-7.

Figure 5-7 Typical Cross Section – Track with Adjacent Walkway



5-1.4 Snow Allowance.

In areas with heavy snowfall, allow for additional roadway width or ditch width to provide sufficient room for snow plowed from the track.

5-2 GRADES AND TRACK PROFILE.

5-2.1 Grades.

Chapter 3 gives gradient criteria for main running tracks. Chapter 7, Paragraph 3 gives gradient criteria for terminal areas.

5-2.2 Vertical Curves.

Vertical curves are required to transition between different grades. Transition rates are different for summits and sags. A summit refers to a convex curve where an ascending grade changes to a flatter grade, where a descending grade changes to a steeper grade, or where an ascending grade changes to a descending grade. Sags are concave curves that occur where an ascending grade changes to steeper grade, where a descending grade changes to flatter grade, or where a descending grade changes to an ascending grade. Note: Avoid locating turnouts in vertical curves. Table 5-1 shows recommended transition rates between grades. Determine the length of track required for these transitions from Equation 5-1. Vertical curves should have a minimum length of 100 ft.

Equation 5-1. Track Transitions

$$\boldsymbol{L = \frac{G_1 - G_2}{r} \times 100}$$

Where:
L = Length of track required for vertical curve (ft)
G1 and G2 = Slope of the two adjacent grades (percent), where ascending grades have a positive value and descending grades have a negative value
r = Rate of change in grade in 100 ft (30.5 m)

Table 5-1 Recommended Transition Rates (r) between Grades

Main Running Track		
Summits	**Sags**	**Operating Application**
0.1	0.05	Average rate where speeds will exceed 15 MPH (24.1 km/hr) and right-of-way length is ample.
0.2	0.1	Average rate where speeds will not exceed 15 MPH (24.1 km/hr) or where transition length is limited.
0.3	0.15	Maximum rate where speeds will exceed 15 MPH (24.1 km/hr).
0.4	0.2	Maximum rate where speeds will not exceed 15 MPH (24.1 km/hr).
Terminal Tracks		
Summits	**Sags**	**Operating Application**
1.0	0.6	Preferred rate for terminal tracks
2	1.2	Maximum rate for terminal tracks

5-2.3 Track Profile.

Avoid a rolling profile (frequent changes in gradient) on main running tracks or terminal tracks in the roadbed or in the final track surface (top of rail elevation). Follow the criteria in Table 3-2 to maintain an acceptably smooth track profile.

5-3 HORIZONTAL CURVES.

5-3.1 Definition.

Railroads are laid out with circular curves using the chord definition. Curvature is measured in degrees, as indicated in Equation 5-2.

Equation 5-2. Curvature

$$D = 2arcsin\left(\frac{50}{R}\right) \text{ or } R = \frac{50}{sin\frac{D}{2}}$$

Where:
D = Degree of curve (decimal degrees)
R = Radius of curve (feet)

5-3.2 Design Criteria.

5-3.2.1 Design Categories.

Table 3-3 shows design categories for horizontal curves.

5-3.2.2 Track Rehabilitation Projects.

During the design of major track rehabilitation projects, to the maximum extent practical, adjust existing curvature to less than 10 degrees for main running tracks and 12 degrees in terminal areas.

5-3.3 Minimum Tangent Length between Reverse Curves.

When curves of different directions immediately follow in sequence (reverse curves), install a length of tangent track between the two curves. The preferred and minimum tangent lengths between reverse curves are:

- Preferred Tangent Length: 100 ft (30.5 m)
- Minimum Tangent Length: 60 ft (18.2 m)

5-3.4 Super Elevation.

For either new design or major rehabilitation, elevate the outer rail in curves above the inner rail by the amount shown in Table 5-2. Ensure designs do not call for a combination of speed and curvature that fall below the bottom-stepped ledger line in the table. Provide ½ inch (13 mm) of super-elevation on all curves in main running tracks wherever possible even when not required by Table 5-2. Do not provide super-elevation in terminal yard tracks.

Provide full super-elevation around the entire curve. For curves with 1-in. (25 mm) super-elevation, run out that elevation (transition back to level) in 40 ft (12.1 m) of tangent at the beginning and end of the curve. Where super-elevation is more than 1in. (25 mm), provide spirals at each end of the curve.

Table 5-2 Design Super-Elevation for Curved Track

Degree of Curvature	Design Operating Speed MPH (km/hr)						
	10 (16)	**15 (21.4)**	**20 (32.2)**	**25 (40.2)**	**30 (48.3)**	**35 (56.3)**	**40 (64.4)**
0.5	NO SUPER-ELEVATION REQUIRED						1.0
1.0					1.0	1.0	1.0
1.5				1.0	1.0	1.5	1.5
2.0			1.0	1.0	1.5	2.0	2.0
2.5			1.0	1.5	1.5	2.0	2.5
3.0		1.0	1.0	1.5	2.0	2.5	3.0
3.5		1.0	1.0	1.5	2.0	2.5	3.0
4.0	1.0	1.0	1.0	1.5	2.0	3.0	3.5
4.5	1.0	1.0	1.5	2.0	2.5	3.5	4.0
5.0	1.0	1.0	1.5	2.0	3.0	4.0	
5.5	1.0	1.0	1.5	2.0	3.0		
6.0	1.0	1.0	1.5	2.0	3.0		
6.5	1.0	1.5	2.0	2.5			
7.0	1.0	1.5	2.0	2.5			
7.5	1.0	1.5	2.0				
8.0	1.0	1.5	2.0				
8.5	1.0						
9.0	1.0						
9.5	1.0						
10.0	1.0						
10.5	1.0		DO NOT DESIGN FOR OPERATION IN THIS RANGE				
11.0	1.0						
11.5	1.0						
12.0	1.0						
Note: Table entries are super-elevation in inches.							

5-3.5 Spirals.

When used, design spiral transition curves as shown in Chapter 5, Section 3.1 of the AREMA Manual. Increase super-elevation uniformly from zero at the beginning of the spiral (at the tangent) to the full elevation at the end of the spiral (where full curvature is reached).

Determine spiral length from Equation 5-3.

Equation 5-3. Spiral Length

$$L_s = 40 \times S$$

Where:
L_s = Length of spiral (feet)
S = Full super elevation (inches)

5-3.6 Increase in Gage on Very Sharp Curves.

Where curves of 12 degrees or more are unavoidable, finished track gage is as follows:

Table 5-3 Finished Track Gage

Curvature Range (degrees)	Track Gage in. (m)
12 to 16	56⅝ (1.438)
14 to 16	56¾

5-4 CLEARANCES.

5-4.1 Clearances to Check.

For either new construction or rehabilitation work, ensure the location and position of all tracks are checked for proper clearances before the final design is prepared and after construction is complete. Provide allowances for future track surfacing (adding ballast and raising track) and for small changes in alignment during maintenance.

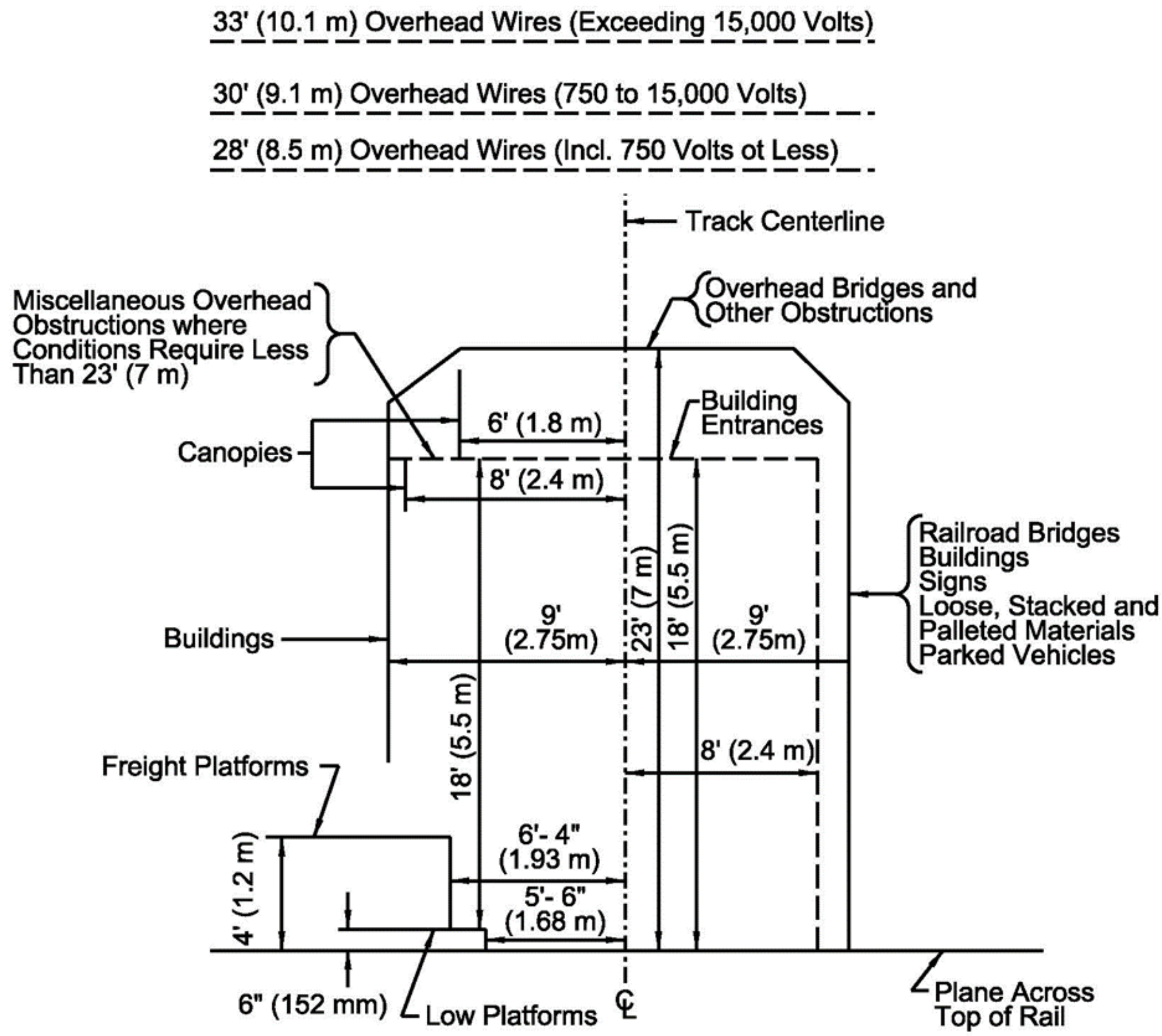
5-4.2 Recommended Minimum.

Minimum clearances are shown in Figure 5-8 and Table 5-4. Vertical clearances are measured from the top of the rail, and horizontal clearances are measured from the center line of track.

5-4.3 State Requirements.

Each State has legal requirements for railroad clearances. These are summarized in a table in Chapter 28, Section 3.6 of the AREMA Manual. When State requirements exceed clearances shown in Figure 5-8 or Table 5-4, use the State requirement.

Figure 5-8 Clearance Diagram for Tangent Track



Note: Protect vertical clearances less than 23' (7 m) and side clearances less than 9' (2.75 m) (other than track appurtenances by an approved type of warning device.

Table 5-4 Overhead and Side Clearances for Tangent Track

Vertical Clearances (from top of rail)	Required Clearance
Overhead wires: (open supply, arc wires, service drops)	
0 to 750 volts	28 ft (8.5 m)
750 to 15,000 volts	30 ft (9.1 m)
15,000 to 138,000 volts	33 ft (10.1 m)
Other overhead wires	28 ft (8.5 m)
Building entrances (including engine-houses)	18 ft (5.5 m)
Overhead bridges	23 ft (7 m)
Other overhead obstructions	23 ft (7 m)
Side Clearances (from track center)	
Buildings	9 ft (2.75 m)
Buildings without platforms requiring delivery of materials	8 ft (2.44 m)
Platforms:	
Freight platforms up to 4' maximum height	6 ft – 4 in (1.93 m)
Low platforms (less than 6" high)	5 ft – 6 in (1.67 m)
Building entrances (other than engine-house)	8 ft (2.44 m)
Canopies over platforms (canopy height < = 18')	8 ft (2.44 m)
Fences, retaining walls, utility poles, and other obstructions	9 ft (2.75 m)
Bridges	9 ft (2.75 m)
Signs	9 ft (2.75 m)
All loose, palleted, and stacked materials	9 ft (2.75 m)
Parked vehicles	9 ft (2.75 m)
Notes: 1. In curves, side clearances will be increased 1½ in. (38 mm) per degree of curvature. 2. For voltages greater than 138,000 volts, see the latest National Electric Safety Code and assume a rail car height of 23 ft. (7 m) to determine required clearance.	

5-4.4 Curved Track.

For each degree of curvature, increase side clearances 1-1/2 in. (38 mm) over that required in Figure 5-8 and Table 5-4. When an obstruction is located adjacent to tangent track, but the track begins to curve within 80 ft (24.4 m) of the obstruction, increase the side clearances by the amounts shown in Table 5-5.

Table 5-5 Clearance Increases Adjacent to Curved Track

Distance from Obstruction to Curved Track ft (m)	Increase in Clearance per Degree of Curvature inch (mm)
0 -20 (0 -6)	1½ (38)
21 – 40 (6.4 – 12.1)	1⅛ (28.6)
41 – 60 (12.5 – 18.2)	¾ (19)
61 – 80 (18.6 – 24.4)	⅜ (9.5)

5-4.5 Minimum Track Centers.

The recommended minimum distance between the center lines of adjacent tracks is given in Table 5-6.

Table 5-6 Track Center Distances

Between	Minimum Distance Between Centerlines ft (m)
New Tracks	15 (4.6)
Existing Tracks	14 (4.3)

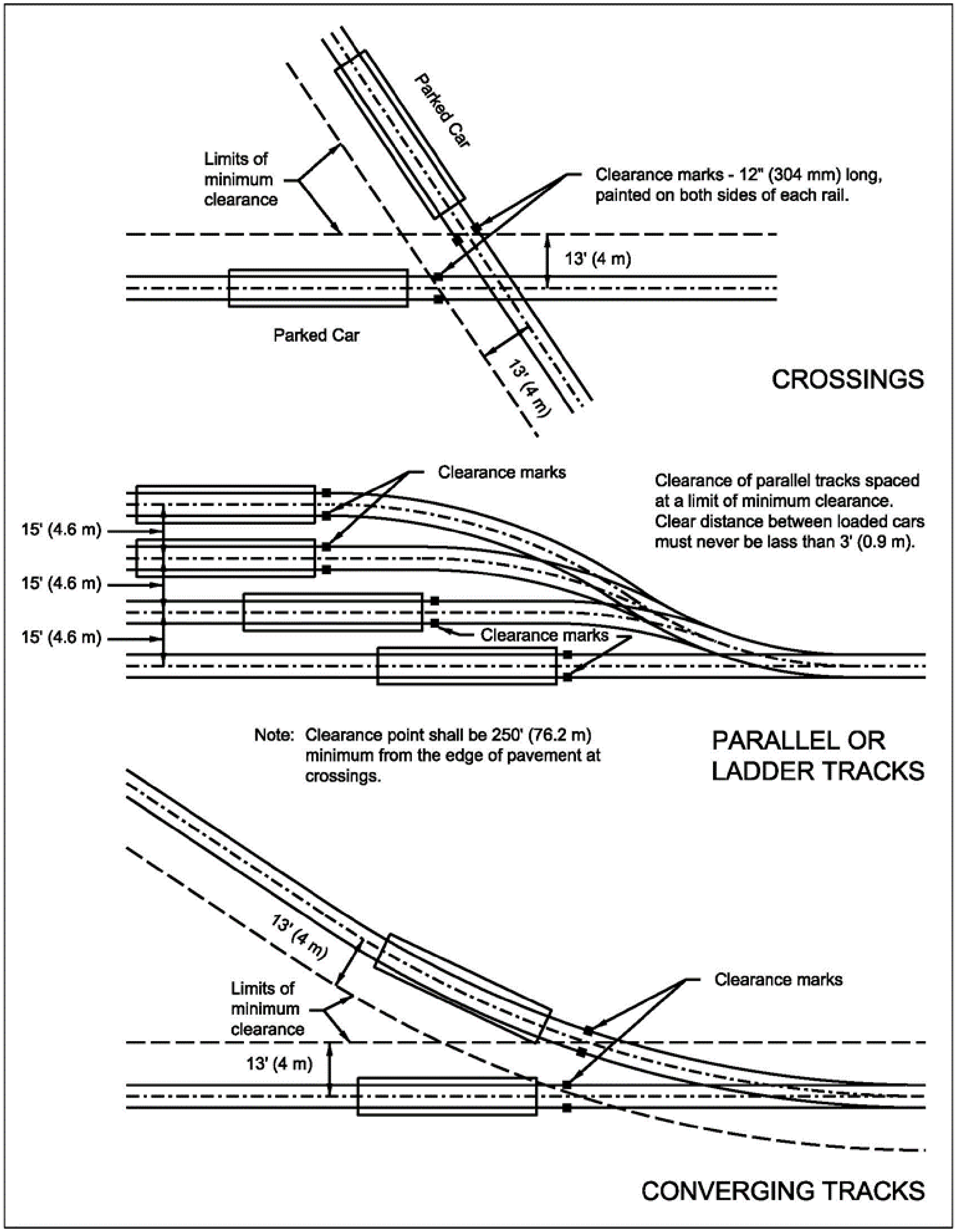
5-4.6 Clearance Points at Turnouts, Ladder Tracks, and Crossings.

Figure 5-9 illustrates how to determine the location of clearance points at turnouts, ladder tracks, and rail crossings. Ensure no rail car or piece of equipment remains standing on a track with any part of it extending past the clearance point (toward the track junction), the clearance point will determine the usable length of sidings, loading, yard, and storage tracks.

- Mark clearance points by a 12-in. (300 mm) yellow bar painted on both sides of the rail base.

- If derails are used, they must be set to derail equipment before it reaches the clearance point.

Figure 5-9 Location of Clearance Points



5-5 TRACK STRUCTURE.

5-5.1 Design Objective.

Among its various functions, the track system distributes the large, concentrated wheel loads longitudinally, laterally, and vertically away from the wheel contact area on the rail surface. A well designed, constructed, and maintained track distributes loads in a relatively uniform fashion, with each component supporting its share of the load. The role of the designer is to select a track structure or changes to an existing track that ensures intended wheel loads are properly supported, without overstressing any of the four main track system components: rail, ties, ballast, and subgrade.

5-5.2 Load Distribution.

As Figure 5-10 shows, when a wheel is centered over a tie, the tie directly beneath the load will generally carry less than half of that wheel load, with the remainder supported by two ties on either side. Beneath the wheel, the pressures are distributed (reduced) approximately as shown in Figure 5-11. With a wheel-rail contact area of about ½ sq in., stresses are reduced from 60,000 psi (414 MPa) at the top of the rail to about 10 psi (.069 MPa) at the depth of the subgrade surface. While the actual load and pressure distributions vary with wheel load, track design, and track condition, the two figures illustrate a realistic case for good track.

Figure 5-10 Example Load Distribution along the Track

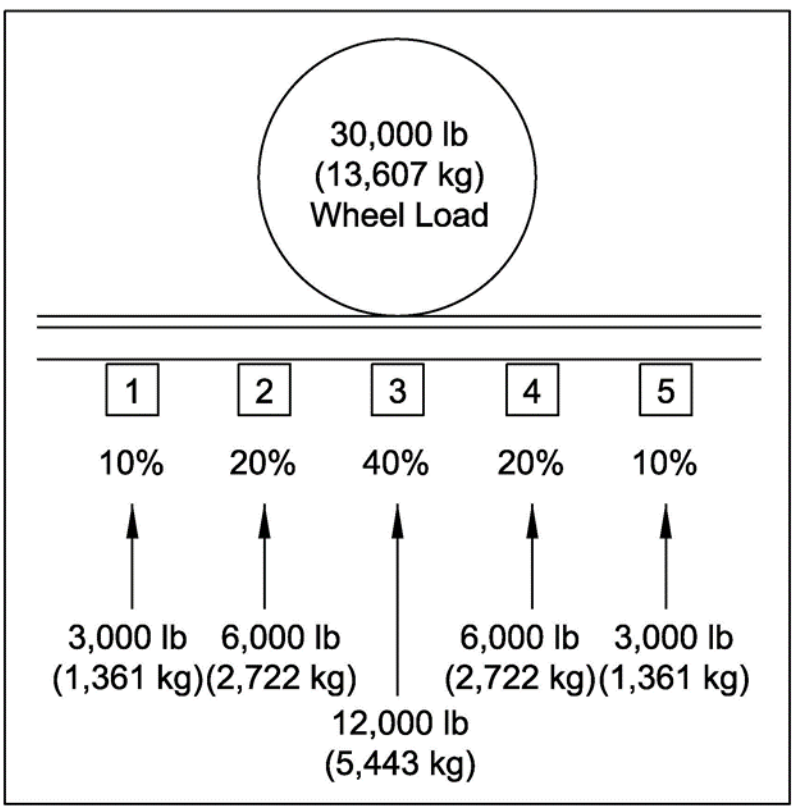
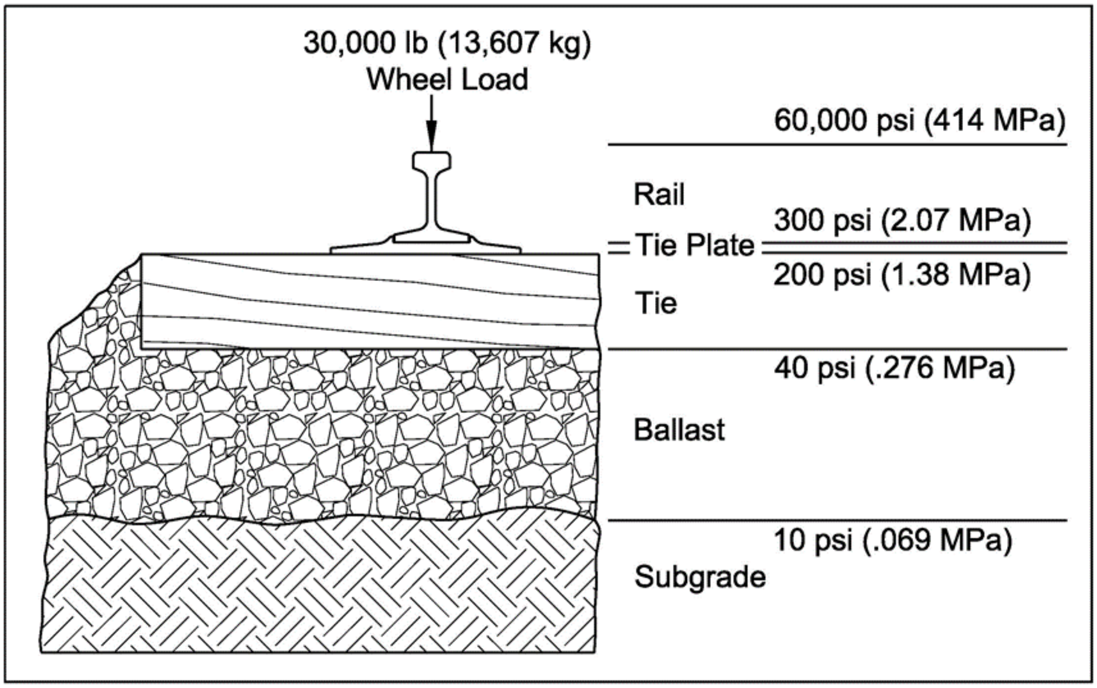


Figure 5-11 Example Vertical Pressure Reduction through the Track



5-5.3 Behavior under Load.

Although track construction is relatively simple, its behavior under load is not. An improvement (or increase in strength) in one track component can increase the load on another. It is not uncommon for an improvement (or increase in strength) of one track component to cause an increased load on another.

5-6 TRACK DESIGN METHODS.

5-6.1 Computer Program Available.

TRACK is the computer program for basic track structure design and is available at the PCASE Internet Site (https://transportation.erdc.dren.mil/pcase/software.aspx) or the Army Transportation Systems Center (CENWO-ED-TX).

5-6.2 Manual Design Procedure.

If computer programs are not accessible or if a computer is unavailable, use the design procedure in Paragraph 7 as an alternative. A disadvantage of this method, however, is that very little data exists to correlate the value of track modulus with the properties of individual rail support components: ties, ballast, and subgrade.

5-7 AREMA DESIGN PROCEDURE (1995-MODIFIED).

5-7.1 Applying the AREMA Method to Military Track.

The AREMA method leaves several choices and judgments open to designers, to be set according to situation and policy. And like most AREMA criteria, the method is also oriented toward those commercial lines that carry medium to heavy traffic volumes (more than 10 million gross tons (9.07 million Metric tons) per year) and operate at medium or higher speeds (more than 40 mph (64.4 km/hr)). The guidance below assumes that most military track operates at relatively low traffic volumes (less than 5 million gross tons (4.54 million Metric tons) per year) and at relatively low speeds (less than 25 mph (40.2 km/hr)), and uses jointed, rather than continuously welded, rail.

For unusual cases where yearly traffic frequencies are expected to exceed 5 million gross tons (4.54 million Metric tons), designers can follow the method directly from Chapter 16 of the AREMA Manual.

5-7.2 Basis for Design.

The AREMA track design method is based on extensive field and laboratory testing conducted between 1914 and 1940. The committee supervising the tests and evaluations was led by Professor Arthur Talbot of the University of Illinois, whose name is often used when referring to the tests and findings. The Talbot Committee found that, when subject to a large number of load repetitions (“millions of groups of car wheels”), the greater the vertical rail deflection under those loads, the faster the track condition deteriorated. From the data and observations collected, AREMA employs a track design method based on limiting or controlling vertical rail deflection.

Figure 5-12 illustrates the general relationship between track deflection and track performance over long time periods. The design criteria in this section limits the deflection of main running tracks to 0.3 in. (7.6 mm) and of auxiliary, storage, spur, and light use tracks to 0.4 in. (10.2 mm). The AREMA track design method uses the beam-on-elastic-foundation model. In this model, the track has two components: the beam, which is the rail, and the elastic foundation, which represents everything below the rail combined. The basic expression in the model relates three main variables: the load on the rail, the stiffness of the track system, and the amount of vertical rail deflection, as shown in Equation 5-4.

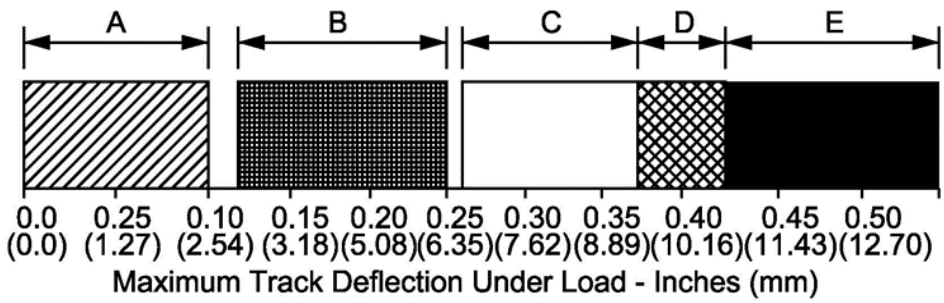
Equation 5-4. Vertical Rail Deflection

$$Y = \frac{P}{(64\ EIu^3)^{.025}}$$

Where:
Y = vertical rail deflection at a point (inches)
P = applied wheel load (including contributions from adjacent wheels) (lb.)
EI = stiffness of the rail, where:
E = modulus of elasticity for steel (30 x 10^6 psi)

I = vertical moment of inertia of the rail section (inches^4)
u = stiffness of rail support, or track modulus (psi)
In this equation, EI represents the stiffness of the “beam” and u the stiffness of the “elastic foundation.”

Figure 5-12 Maximum Track Deflection and Long-Term Track Performance



Range	Long Term Track Performance
A -----	Excessively stiff track.
B -----	Track of heavier construction which wil hold up well under large traffic volumes (> 15 GT (15.2 MT)).
C -----	Track suitable for lower thraffic volumes (< 15 GT (15.2 MT)).
D -----	Sidings and other auxiliary tracks on low traffic lines.
E -----	Track which will deteriorate quickly: only suitable for occasional movements with cars less than 100 tons (101.6 MT) capacity.

Note: Deflections do not include any play or looseness between track components.

5-7.3 Design Load and Wheel Spacing.

5-7.3.1 Design Load.

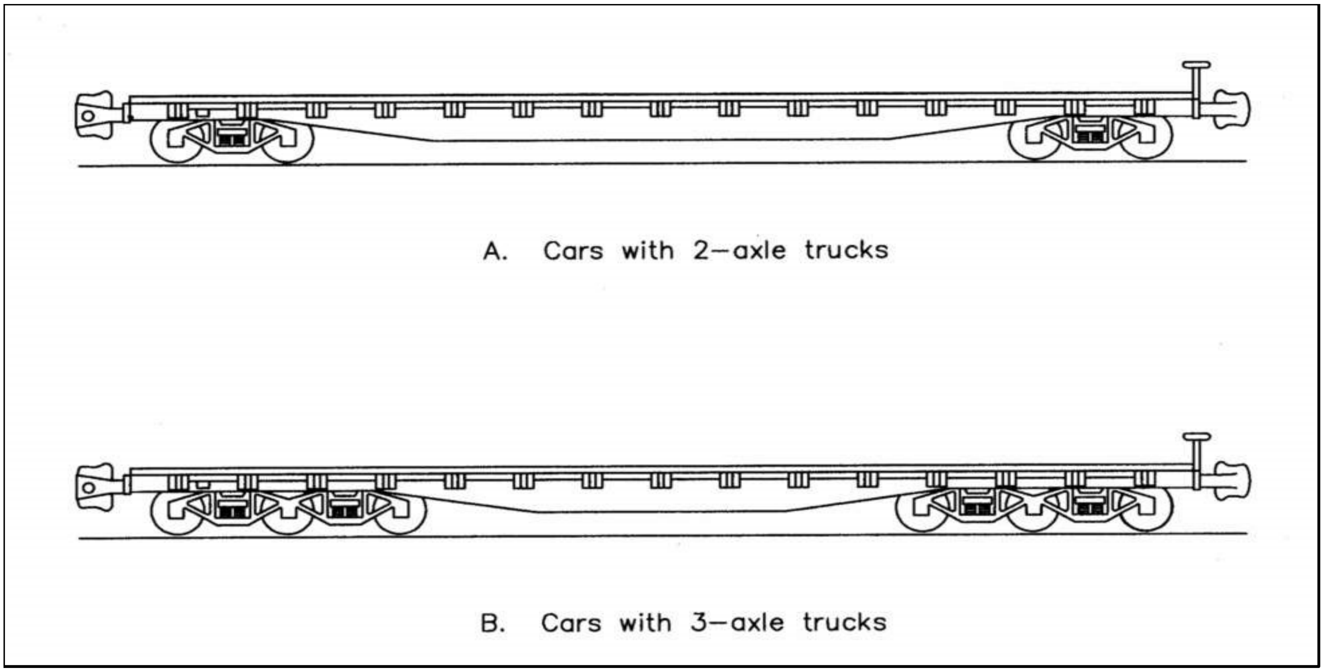
Select the design wheel load from Table 2-2, based on the most common, heaviest car expected to travel over the track.

5-7.3.2 Wheel Spacing.

Figure 5-13 shows the two most common wheel configurations. Most cars have two-axle trucks and the design wheel configuration is that in drawing (A), with an average 75-in. (1905 mm) wheel spacing. The 140- ton (127 MT) series flat cars, for carrying M-1 tanks and other heavy vehicles, and some 100-ton (90.7 MT) flat cars have 3- axle trucks; their design wheel configuration is drawing (B), with 66-in. (1676 mm) wheel spacing.

Evaluate the track assuming that a wheel is centered over a tie, with an adjacent wheel on either side contributing to the loads, deflections, and stresses - as occurs when two cars are coupled together. Referring to Figure 5-13(A), the maximum tie, ballast, and subgrade loads occur under wheels one and four (counting from the left), while the maximum rail bending stress occur at wheels two and three. For the wheel configuration in Figure 5-13(B), the maximum tie, ballast, and subgrade loads occur under wheels two and five, while the maximum rail bending stress occur at wheels three and four. The effect of wheels farther than 100 in. (2540 mm) from the design wheel is negligible.

Figure 5-13 Design Wheel Configurations



5-7.4 Select Track Modulus (u).

The track modulus values listed in Table 5-7 are suggested starting points for design. In the table, track type “main” refers to main running tracks, while “auxiliary” includes sidings, wyes, loading, spur, storage, interchange, and light use tracks.

Table 5-7 Suggested Design Track Modulus Values

Track Type	Design Wheel Load Range – 1,000's of pounds (1,000's of kilograms)					
	20 – 25 (9.1 - 11.3)	25 - 30 (11.3 - 13.6)	30 – 35 (13.6 - 15.9)	35 – 40 (15.9 - 18.1)	40 - 45 (18.1 - 20.4)	45 – 50 (20.4 - 22.7)
Main	1500	1800	2000	2300	2600	2900
Auxiliary	1200	1300	1500	1700	2000	2200

5-7.5 Select Rail Size and Section.

Use Equation 5-5 to determine a minimum rail weight.

Equation 5-5. Minimum Rail Weight

$$W_o = 315 - \frac{21200}{\left(\frac{P}{1120}\right)(\alpha) + 67}$$

Where:
W_o = Weight of rail (lb./yd.)
P = Design wheel load (lb.)
α = Impact factor, where:
α = 1, where design operating speed is 25 mph or less.
α = 1.4, where design operating speed is more than 25 mph.

Select a rail section from Table 5-8 of equal or greater weight than calculated above.

Table 5-8 Rail Sections

Rail Section	Moment of Inertia, I (inches^4)	Section Modulus to Base, Z_b (inches^3)
115 RE	65.6	22.0
132 RE	88.2	27.3
133 RE	86.0	27.0
136 RE	95.4	28.2

5-7.6 Determine Moment and Loading Coefficients.

The moment and loading coefficients account for the effects of wheels adjacent to the design wheel. Adjacent wheels reduce rail moment and increase tie, ballast, and subgrade load. Calculate x_1 using Equation 5-6. (x_1 should normally range between 28 and 40).

Equation 5-6. Distance from Design Wheel Load to Point of Zero Bending

$$x_1 = 82\sqrt[4]{\frac{I}{u}}$$

Where:
x_1 = Distance from design wheel load to point of zero bending moment (inches)
I = Vertical moment of inertia of rail section (in.^{4})
u = Stiffness of rail support, or track modulus (psi)

Determine coefficients C_m and C_d as follows. For most design situations, and for cars with either 2-axle or 3-axle trucks, the rail moment coefficient (C_m) can be taken as 0.8. The load coefficient C_d can be taken from the following table. Intermediate values of Cd can be interpolated.

Table 5-9 Values for C_d

X_1 =		28	30	32	34	36	38	40
Design Wheel Spacing	66 in (1.67 m):	1.24	1.30	1.36	1.44	1.54	1.62	1.70
	75 in (1.91 m):	1.08	1.15	1.22	1.30	1.36	1.42	1.50

5-7.7 Check Rail Bending Stress.

Use Equation 5-7 to check that rail bending stress is less than 32,000.

Equation 5-7. Rail Bending Stress

$$f_0 = \frac{(0.318 P_d C_m X_1)}{Z_b}$$

Where:
f_o = Maximum flexural stress (psi)
P_d = Dynamic (design) wheel load (lb) from Table 2-2
C_m = Moment coefficient
X_1 = Distance from wheel load to point of zero bending moment (inches)
Z_b = Section modulus of rail base, from Table 5-8 (cu in.)

5-7.8 Ties and Tie Spacing.

Choose a trial tie spacing and calculate the maximum rail seat load using Equation 5-8:

Equation 5-8. Maximum Rail Seat Load

$$q_o = \frac{0.39 P_d C_d S}{X_1}$$

Where:
q_o = Maximum rail seat load (lb)
P_d = Dynamic (design) wheel load (lb) from table 2-2
C_d = Load coefficient for adjacent wheels
S = Tie spacing (inches). Typical spacings range from 19.5 in. (495 mm) to 22 in. (558 mm)
X_1 = Distance from wheel load to point of zero bending moment (inches)

Select tie size, either 6-in. x 8-in. x 8.5 ft (152 mm x 203 mm x 2.6 m), or 7-in. x 9-in. x 8.5 ft (178 mm x 229 mm x 2.6 m). Check tie bending stress using Equation 5-9 or 5-10. If f_t is greater than the maximum value of f_t in Table 5-, choose a larger tie size or decrease tie spacing.

Equation 5-9. Bending Stress for 6-in x 8-in (152 mm x 203 mm) Ties

$$f_t = \frac{q_o}{29}$$

Equation 5-10. Bending Stress for 7-in x 9-in (178 mm x 229 mm) Ties

$$f_t = \frac{q_o}{52}$$

Where:
f_t = Flexural stress on underside of tie below rail seat (psi)
q_o = Maximum rail seat load (lb.)

Table 5-10 Maximum Allow Values for f_t

Tie Material	**Maximum Allowable Value for f_t psi (MPa)**
Oak	1400 (9.65)
Mixed Hardwoods	1100 (7.58)
Longleaf Yellow Pine	1000 (6.89)
Douglas Fir	800 (5.52)

5-7.9 Ballast and Subgrade.

Determine ballast surface stress from Equation 5-11, with p_m = 65 psi (.448 MPa) as a suggested limit. If p_m exceeds 65 psi, choose a larger tie and/or decrease tie spacing.

Equation 5-11. Ballast Surface Stress

$$p_m = \frac{q_o}{A_b}$$

Where:
p_m = Ballast surface stress (psi). qo = Maximum rail seat load (lb.)
A_b = Effective bearing area of ½ tie on ballast under one rail (sq. in.)
For 6 x 8 (152 mm x 203 mm) ties, A_b = 270
For 7 x 9 (178 mm x 229 mm) ties, A_b = 312

Select design subgrade bearing capacity (pc) according to results of soil tests or other data. (In the absence of other guidance, the design bearing capacity for cohesive soils is the same as the unconfined compressive strength). Determine ballast depth from Equation 5-12:

Equation 5-12. Ballast Depth

$$h = \frac{\left(50\frac{p_m}{p_c}10\right)^{0.74}}{2.54}$$

Where:
h = Ballast depth in inches
p_m = Ballast surface stress (psi)
p_c = Design subgrade bearing capacity (psi)

5-8 SUBGRADE.

5-8.1 Subgrade Stability and Track Performance.

The subgrade is the prepared earth on which the railroad ballast section and track structure are built. If the subgrade does not have sufficient stability, it will be impossible to maintain proper track alignment, profile (surface), and cross level.

5-8.2 Soil Investigation.

Prior to initial design of the track structure, perform a geotechnical investigation along the proposed alignment to determine soil type, strength, bearing capacity, location of groundwater tables, natural water content, and compaction characteristics. Additional geotechnical borings, laboratory testing, and engineering analysis are required in areas where bridges or other special structures are to be constructed. Chapter 1, Section 1.1 of the AREMA Manual provides recommendations for geotechnical investigations. The spacing and depth of borings will be project specific and developed with the assistance of a geotechnical engineer.

5-8.3 Design of Cuts and Fills and Subgrade Preparation.

Chapter 1, Section 1.2 of the AREMA Manual provides recommendations for design of cuts and fills and subgrade preparation. Table 1-1-10 of the AREMA Manual indicates soils types and their suitability as railroad subgrades.

5-8.4 Track Structure Design Bearing Capacity - Cohesive Soils.

For cohesive soils, and for track expected to carry the usual military traffic level of less than 5 million gross tons per year, set design bearing capacity for the track structure at the soil's unconfined compressive strength at its natural water content. For unusual cases, where annual traffic volumes are projected at higher than 5 million gross tons (4.5 million Metric tons), use 80 percent of the unconfined compressive strength as the design bearing capacity.

5-8.5 Soil Stabilization.

Information on the use of soil stabilization and the design and construction of soil stabilized subgrades is presented in UFC 3-250-11. In frost areas, use soil stabilizers with caution and only after intensive laboratory testing, including a frost susceptibility test and a freeze-thaw durability test.

5-9 FROST DESIGN MODIFICATIONS.

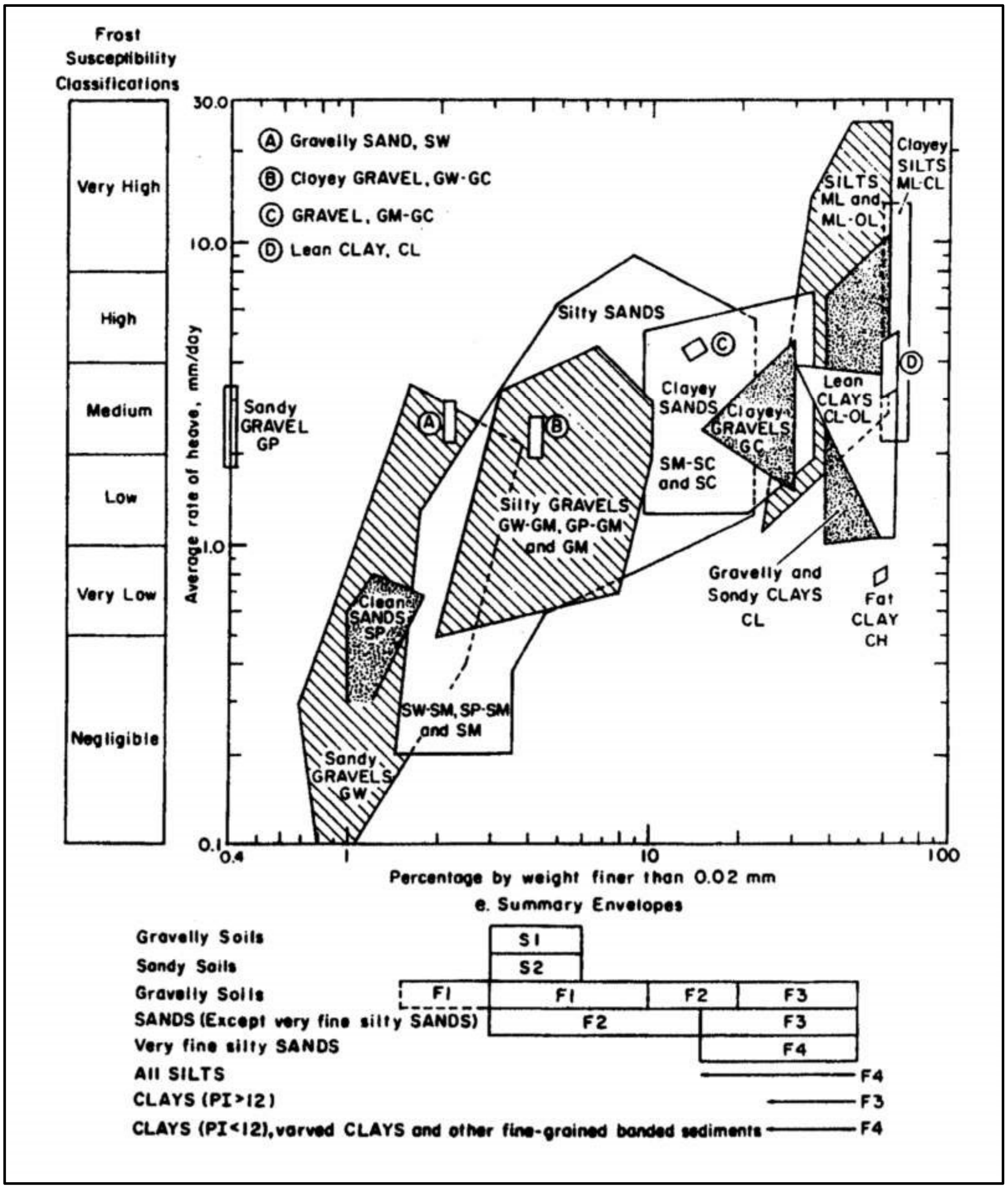
5-9.1 Frost Heave Conditions.

Frost heaving is the rising of the soil due to the growth of ice lenses or ice segregation during freezing. There are three basic conditions that must be present for ice segregation to occur: a frost susceptible soil, a source of water, and freezing temperatures. A change in any of the three conditions impacts the amount of heave.

5-9.2 Identifying Frost Susceptible Soils.

For design purposes, the potential for ice segregation is often expressed as a function of grain (or particle) size. Most organic, non-uniform soils containing 3 percent or more by weight of particles smaller than 0.02 mm are considered frost susceptible. Consider gravel, well graded sands and silty sands, especially those approaching the theoretical maximum density curve, that contain 1.5 to 3 percent of particles smaller than 0.02 mm as possibly frost susceptible and subject to laboratory frost susceptibility tests. Expect considerable ice segregation in uniform sandy soils with greater than 10 percent smaller than 0.02 mm. Figure 5-14 illustrates a method for determining the frost susceptibility of soils.

Figure 5-14 General Method for Determining the Frost Susceptibility of Soils



5-9.3 Water Source.

Usually, the water source is an underlying groundwater table, a perched aquifer, or infiltration from the overlying layers.

5-9.4 Frost Depth.

Future track maintenance costs are reduced if the design depth of frost below the top of the ballast is at least 60 percent of the expected local frost depth. Establish expected frost depth using local records, experience or building practices. If these are unavailable, use the frost depth provided in UFC 3-301-01.

5-9.5 Alternate Frost Depth Procedure.

Use this procedure for fine grained soils of relatively uniform composition at different depths.

Determine the Air Freezing Index - the number of degree days (above and below 32 °F (0 degrees C)) between the highest and lowest points on the cumulative degree day curve for a freezing season. For the design air freezing index, use the 3 coldest years in the last 30 years of record, or use the average index and multiply it by 1.75. (If fewer than 30 years of data are available, use the air freezing index for the coldest year in the last 10-year period). If local records are unavailable, use the values directly from either Figure 5-15 or the PCASE WORLD INDEX program.

Figure 5-15 Design Air Freezing Indexes in CONUS

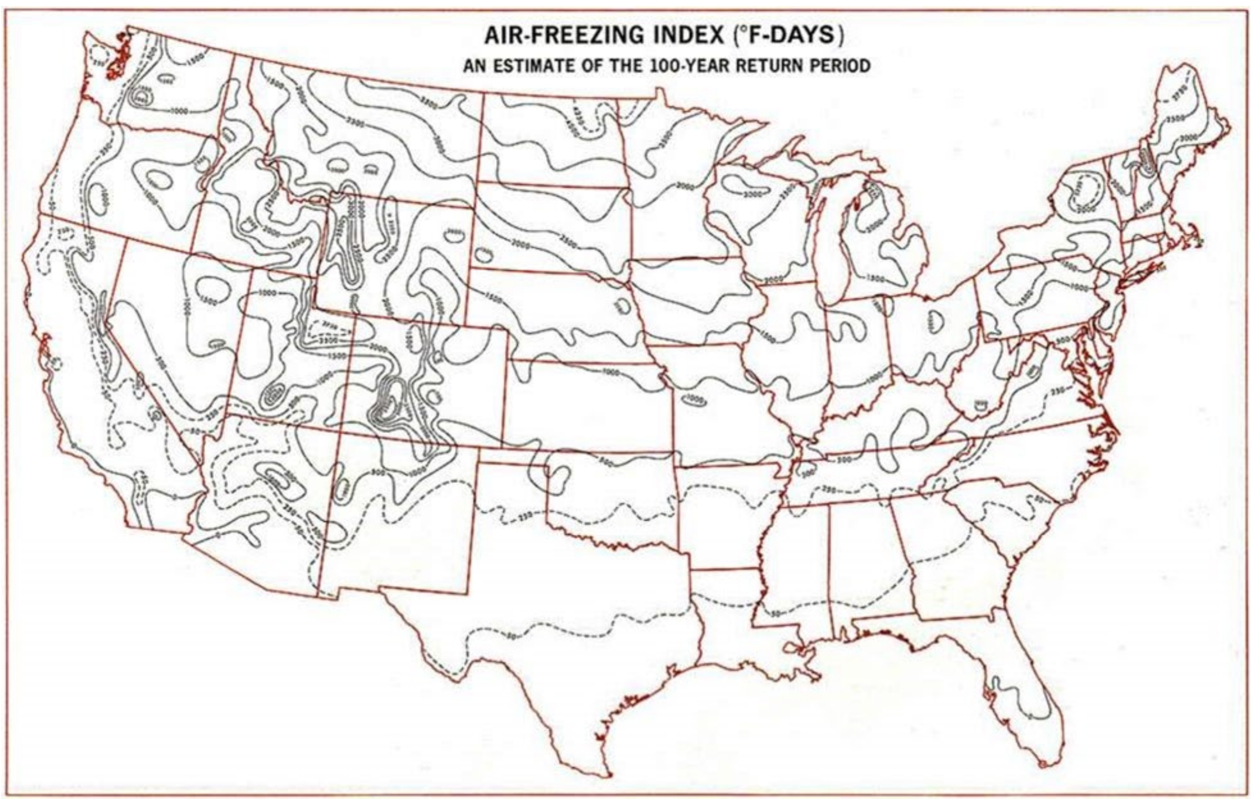
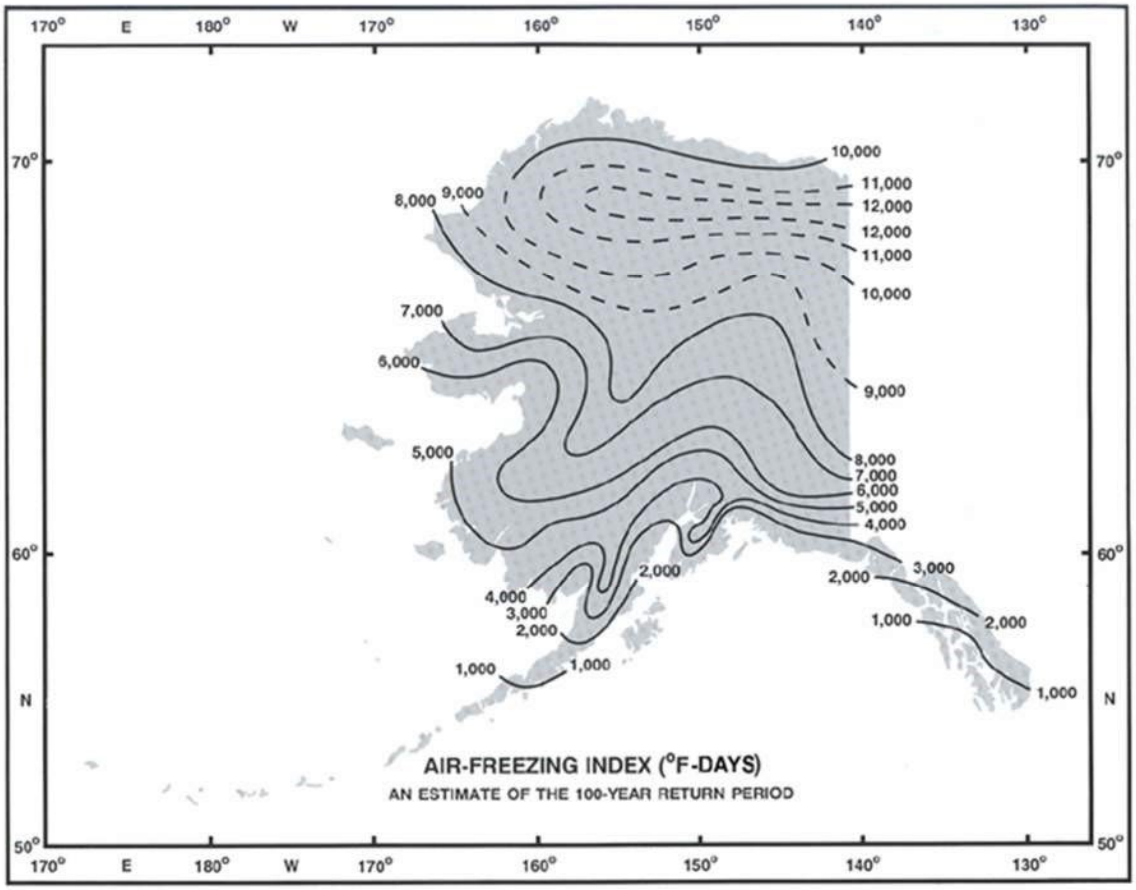
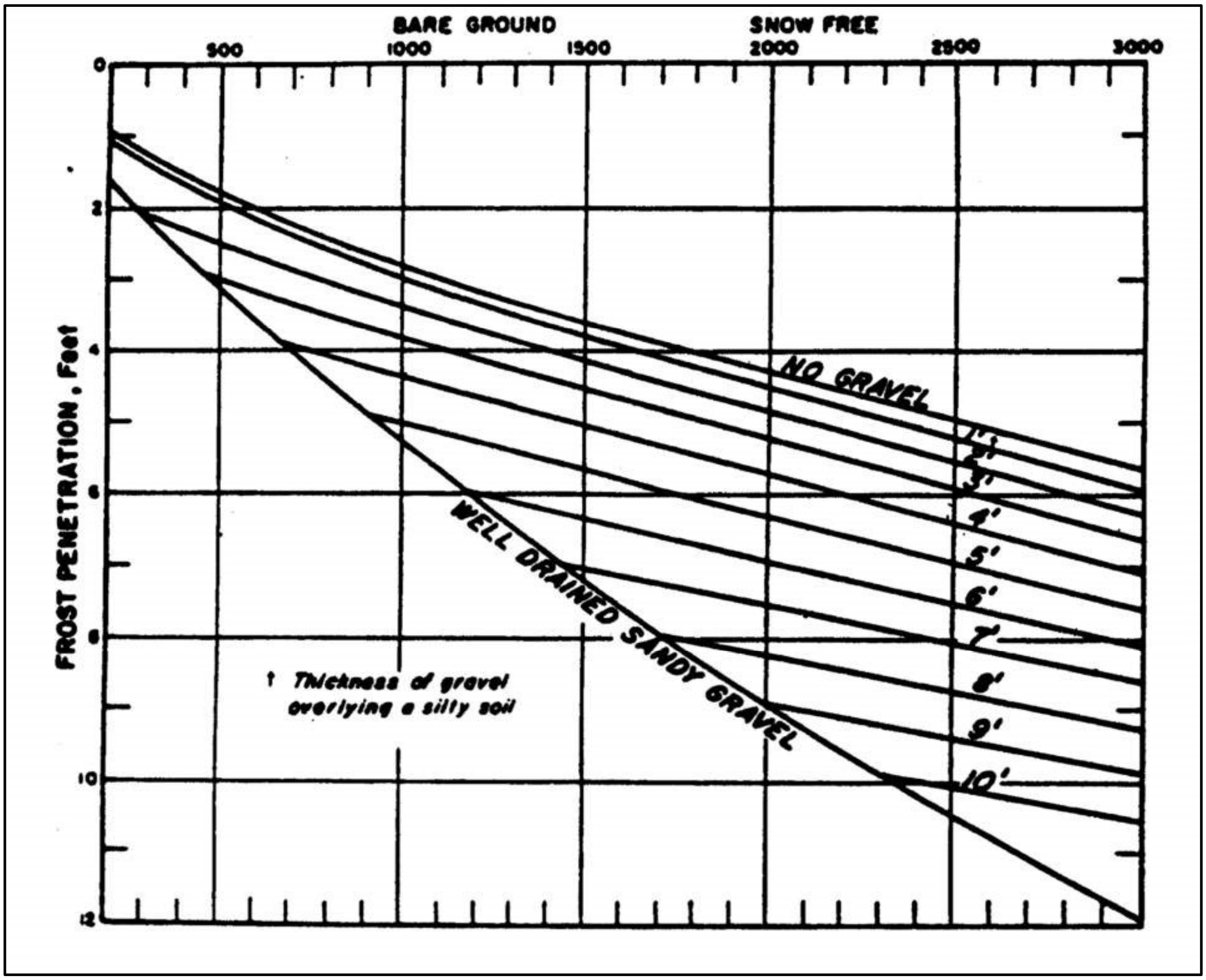


Figure 5-16 Design Air Freezing Indexes in Alaska



Determine the frost depth using Figure 5-17. The gravel thickness in this figure is the total depth of ballast and sub-ballast. Multiply the frost penetration value by 0.6. If the resulting number is smaller than the gravel thickness, then there is an adequate amount of ballast and sub-ballast in the cross section. If the resulting number is larger, additional ballast and/or sub-ballast should be added and the thickness recalculated.

Figure 5-17 Air Freezing Index/Surface Cover/Frost Penetration Relationship



5-9.6 Alternate Design Procedure.

An alternate method of designing for the effects of frost is to reduce the effective strength of the soil to compensate for the thaw-weakening period, similar to a reduced strength pavement design.

5-9.7 Methods for Reducing Frost Effects.

5-9.7.1 Additional Ballast/Sub-ballast.

If more than 40 percent of the total frost depth is in the frost susceptible subgrade, add non-frost susceptible material (clean ballast or sub-ballast) to the roadbed.

5-9.7.2 Geotextiles.

Geotextiles are sometimes used to prevent particle migration at the subgrade/sub-ballast interface during the spring thaw. Contamination of an otherwise clean ballast and sub-ballast by subgrade soil can turn a non-frost susceptible material into a frost susceptible material. The application of geotextiles is covered in AREMA Chapter 1, Part 10.

5-9.8 Transition Zones.

A gradual transition is required between areas with significantly different frost heave behavior. The transition distributes differential heave over a distance and thus reduces its detrimental effects. Transitions between cuts and fills and at culvert crossings and bridge approaches are typically 75 to 100 ft. (22.9 m to 30.5m) long.

5-9.9 Construction Procedures.

Excavate the subgrade and scarify to a predetermined depth based on field conditions. Then windrow and blade to achieve adequate blending. This ensures a high degree of uniformity of soil conditions and eliminates any isolated pockets of soil with higher or lower frost susceptibility. Remove isolated pockets of either low or high frost susceptible material. In these cases, excavate the soil to the full frost depth and replaced with the surrounding soil. Remove stones (6-in. in diameter or larger) or large roots from any fill in the full depth of the frost penetration. This includes any stones encountered during subgrade preparation. Failure to remove these items results in track roughness as the stones and roots are gradually heaved upward. In rock excavations, provide positive drainage so that no pockets of water are left in the zone of freezing. The irregularity of the isolated pockets can cause non-uniform heaving. At the transition between cut and fill sections, use transition sections as previously discussed. Frequently, rock joints and fractures are full of frost susceptible soil. Clean out rock joints or fractures encountered in the subgrade to the full depth of frost penetration and replace these joints with non-frost susceptible material.

5-10 DRAINAGE.

5-10.1 Importance.

Although not a component of the track or roadbed, drainage (or lack of it) has a major impact on track strength and longevity. Without proper drainage, track will fail to perform as designed or intended.

5-10.2 Design Criteria.

Use UFC 3-201-01, Chapter 3 for design and construction of drainage structures, except as modified by the following paragraphs. If required by a commercial railroad, use more restrictive criteria in lieu of these requirements.

5-10.3 Side Ditches.

Most commonly, drainage is provided by open ditches running parallel to the track. In terminals and in other level areas, use inlets, sub-drainage, or other alternative drainage designs if required.

To prevent a significant loss of strength in the subgrade, ensure side ditches provide ample capacity and flow rate. Design ditch size based on the expected rainfall runoff and the contribution from other drainage that empties into the ditches. Design criteria for estimating runoff and determining ditch size is found in UFC 3-201-01.

5-10.3.1 Capacity and Flow Rate.

To provide adequate capacity, design side ditches to ensure the water surface elevation does not rise above the top of subgrade for the 50-year storm. To provide an adequate flow rate, the minimum gradient for side ditches is 0.30 percent.

5-10.3.2 Sub-drainage.

While not a desirable practice, there are some areas where the bottom of the ballast section cannot be installed or raised above the surrounding ground level, and standard side ditches cannot be dug (or would not provide sufficient flow). In these cases, install sub-drainage as shown in Figure 5-18.

5-10.4 Culverts.

Chapter 1, Part 4 and Chapter 8, Parts 10 and 16 of the AREMA Manual provide design criteria and specifications for railroad culverts. Ensure all culvert pipe conforms to current AREMA recommendations or specifications for culvert pipe under railroads. Size culverts to meet the following hydraulic criteria:

- The water surface elevation for the 25-year storm will not rise above the crown of the culvert.
- The water surface elevation for the 50-year storm will not rise above the top of the subgrade.
- If located in a FEMA-designated floodplain, size the culvert opening to meet FEMA's water surface elevation rise criteria if applicable.

Provide a minimum cover of 2.5 ft. (0.76 m) from the bottom of the tie to the top of the culvert. Less cover is authorized in low clearance situations. Perform a structural analysis to determine the appropriate culvert strength for each situation. Design culverts under track for Cooper E80 loading. Ensure culvert materials provide a life expectancy of 50 years.

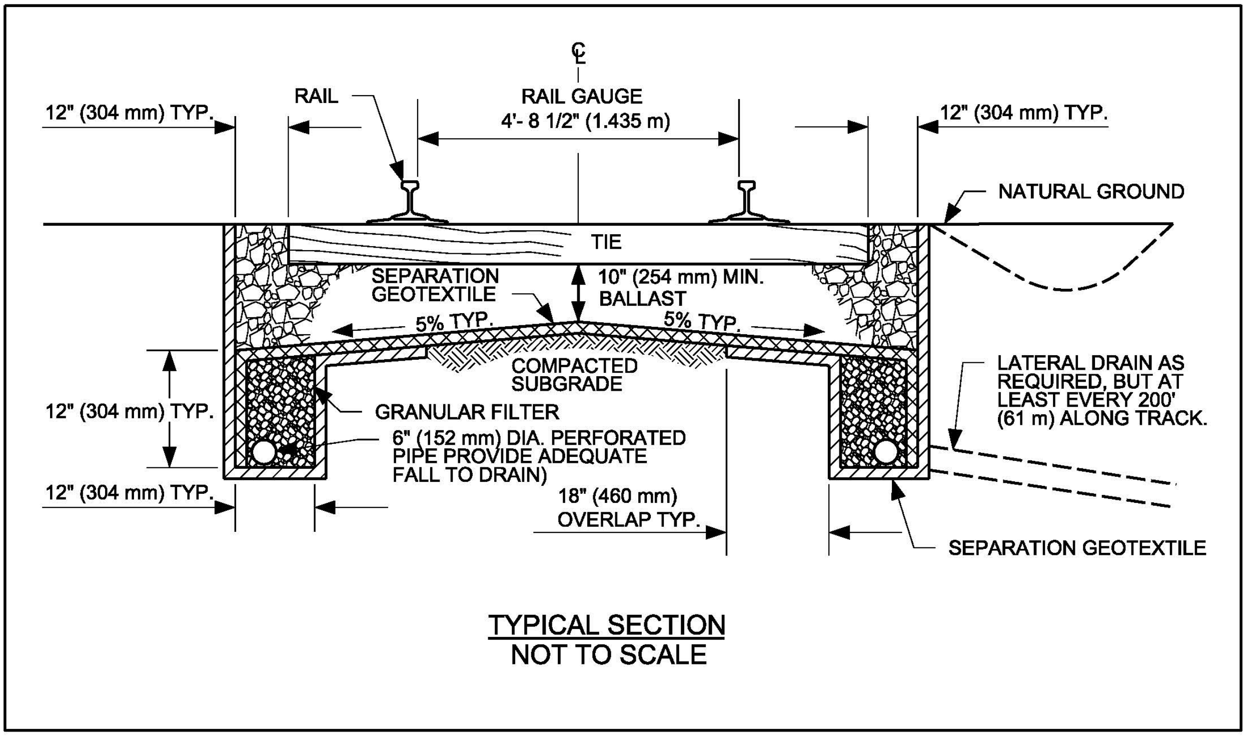
5-10.5 Bridges.

Paragraph 6-2 provides structural design criteria for bridges. Size bridges over waterways to meet the following hydraulic criteria:

- The water surface elevation for the 25-year storm does not rise above the low chord of the bridge.
- The water surface elevation for the 50-year storm does not rise above the top of the adjacent subgrade.

- If located in a FEMA-designated floodplain, size the bridge opening to meet FEMA's water surface elevation rise criteria.

Figure 5-18 Required Sub-drainage where Open Side Ditches cannot be Installed



5-11 GEOTEXTILES.

5-11.1 Application under Track.

Geotextiles are sometimes used under the track to provide for filtration and/or separation of ballast and subgrade or ballast and sub-ballast, drainage functions, or reinforcement of the subgrade. Common locations for the installation of a geotextile under track are:

- Highway-railroad grade crossings.
- Locations with poor subgrade.
- When rebuilding track with a history of excessive loss of profile (surface) and frequent track maintenance requirements.
- Turnouts. See Figure 5-19.
- Bridge approaches. See Figure 5-20.
- Rail crossings.

Recent industry studies have shown that geotextiles have not always been effective under track. Thus, before deciding to install a geotextile, conduct a thorough analysis of the site to assure that a geotextile will accomplish its intended purpose.

5-11.2 Material and Installation Specifications.

Ensure geotextiles, and their installation, conform with the specifications in Chapter 1, Part 10 of the AREMA Manual. Install geotextile under track deep enough that it is not disturbed during tamping/surfacing of the track. It is recommended that geotextile and geogrid be installed underneath a layer of sub-ballast as shown in Figure 5-6 to protect it from damage during tamping/surfacing of the track.

5-11.3 Design Criteria.

Use Chapter 1, Part 10 of the AREMA manual for the design of geotextile and geogrid applications. Geotextile manufacturers provide design guidance on the use of geogrids to support track construction equipment on low strength subgrades.

5-11.4 Drainage Applications.

Lighter weight geotextiles are often useful for drainage applications outside of the track structure, especially in sub-drainage.

Figure 5-19 Geotextile Installation under a Turnout

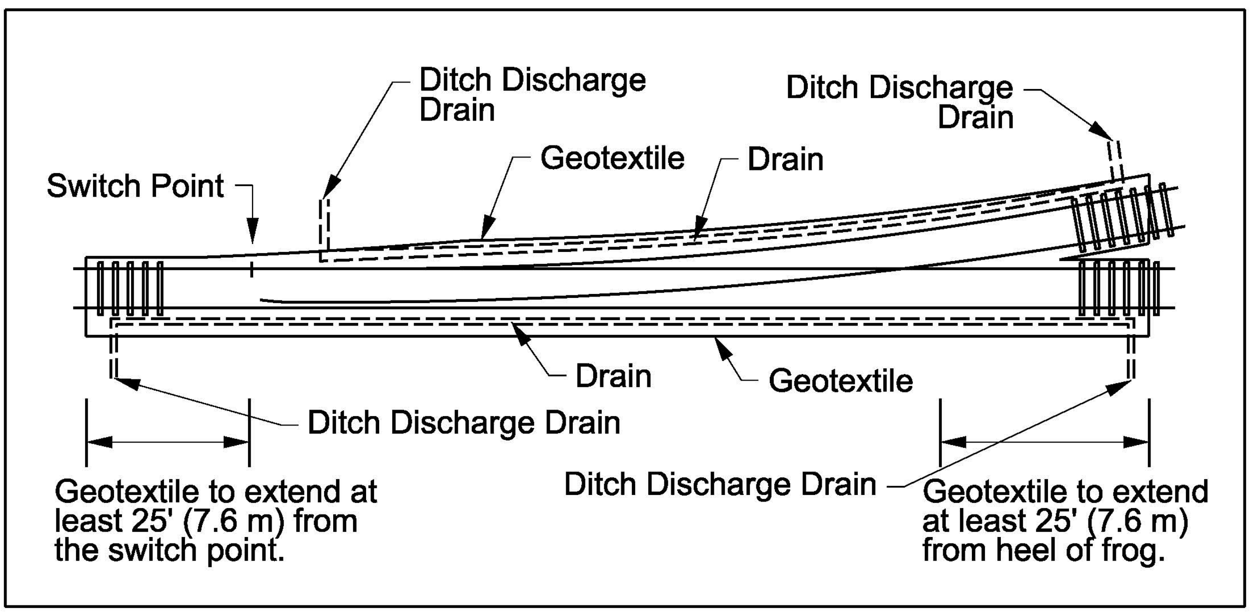
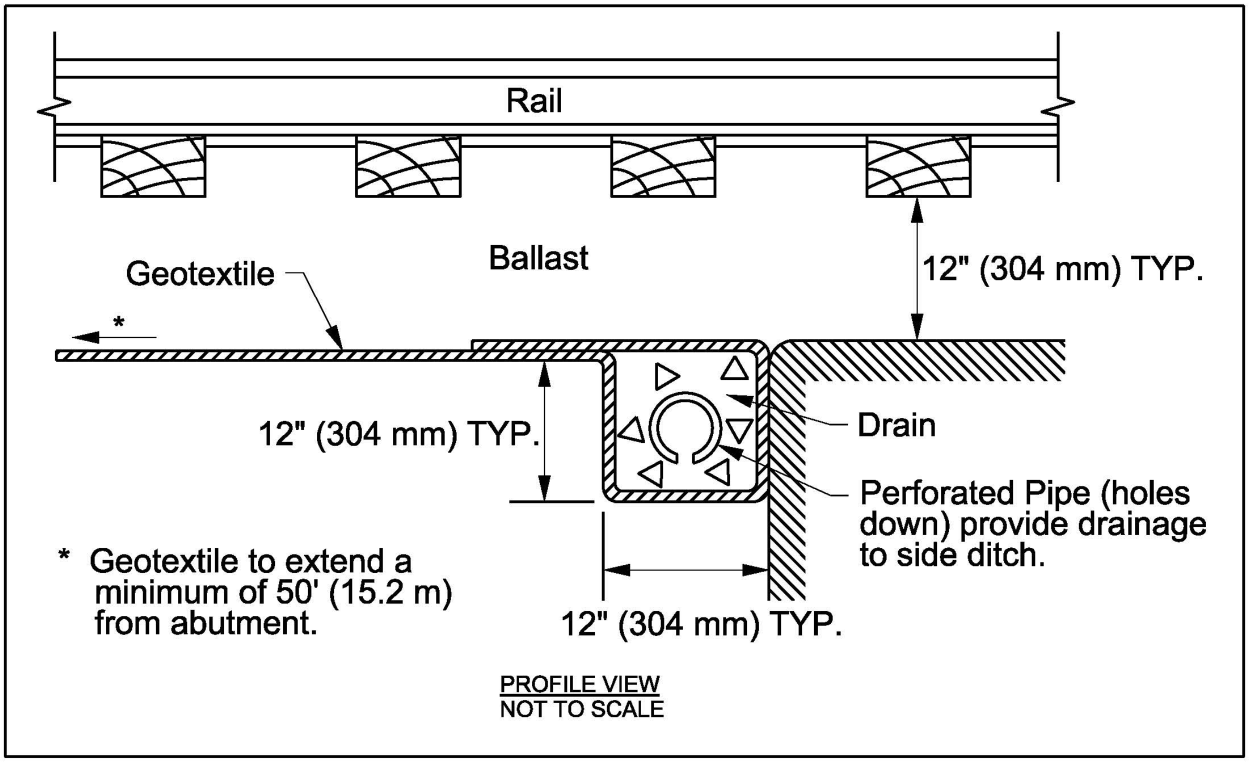


Figure 5-20 Geotextile Installation at a Bridge Abutment



5-12 BALLAST.

5-12.1 Purpose.

Ballast performs four primary functions:

- Distributes wheel loads at reduced pressure to the subgrade.
- Restrains the track laterally and longitudinally.
- Helps maintain track surface.
- Allows track structure to drain.

5-12.2 Material Type.

As ballast depends on high friction and interlock to be effective in restraining track and must also withstand large loads, ensure ballast consist of a hard angular crushed rock or crushed slag.

Common rock materials suitable for ballast are granites, traprocks, quartzites, dolomites, and hard limestones. As limestones degrade, they tend to produce fine particles that cement together, and are thus not the best ballast choice if other hard rock material is economically available. Crushed slag can also vary greatly in quality and suitability for good ballast.

5-12.3 Gradation.

Table 5-11 gives recommended AREMA ballast gradations. Use Size 4A or 4 between the top of the tie and the sub-ballast or subgrade. Use Size 5 ballast around turnouts to construct walkways to facilitate easier walking for switching operations. AREMA ballast Size 4 is identical to ASTM C33 Size 4. ASTM C33 Size 56 is close to AREMA Size 5.

Table 5-11 Recommended Ballast Gradations

Size No.	Nominal Size Square Opening in. (mm)	Amounts Finer Than Each Sieve (Square Opening) Percent by Weight							
		2½ in. (64 mm)	2 in. (50 mm)	1½ in. (37 mm)	1 in. (25 mm)	¾ in. (19 mm)	½ in. (13 mm)	⅜ in. (9.5 mm)	No. 4 (4.75 mm)
4A	2 to ¾ (50 to 19)	100	90-100	60-90	10-35	0-10		0-3	
4	1½ to ¾ (37 to 19)		100	90-100	20-55	0-15		0-5	
5	1 to ⅜ (25 to 9.5)			100	90-100	40-75	15-35	0-15	0-5

For smaller projects, where less than 200 tons (181 Metric tons) of ballast is needed, and where the nearest suppliers do not stock AREMA gradations, substitute the following ASTM gradations: Size 4 for AREMA 4, and Size 56 for AREMA 5.

5-12.4 Depth.

Determine the appropriate ballast depth (or the total of ballast and sub-ballast depth) by conducting a structural analysis using the computer program specified in Paragraph 6. The manual method described in Chapter 5, Paragraph 7 is acceptable, but not preferred.

For wood and engineered composite ties, the minimum depth of ballast from the bottom of the tie to the subgrade is 8 in. (203 mm). If sub-ballast is used, the minimum depth of ballast is 6 in. (152 mm). For steel ties, the minimum depth of ballast from the top of the tie is 10 in. (254 mm) regardless if sub-ballast is used. In most cases, main running tracks require more ballast.

5-12.5 Cross-Section.

Figures 5-1 through 5-6 show standard ballast shoulder widths and side slopes. In finished or resurfaced track, the top of ballast ranges between the top of the tie and 1 in. (25 mm) below. Six inches (152 mm) is the minimum width for shoulder ballast. Increase shoulder ballast width to 12-in. (300 mm) for track with continuously welded rail.

5-13 SUB-BALLAST.

5-13.1 Purpose.

Sub-ballast is a layer of material between the top ballast and subgrade with a gradation finer than the top ballast and coarser than the subgrade. Sub-ballast is often cheaper than top ballast and used to reduce total ballast cost or to provide a filter layer between the top ballast and a fine-grained subgrade. Figures 5-2, 5-4, 5-5, and 5-6 show a sub-ballast layer. It is recommended that sub-ballast be used for all new track construction and for rehabilitations replacing the track structure.

5-13.2 Application.

A sub-ballast layer is recommended for most new construction. In addition to providing a filter to keep subgrade particles from working up into and fouling the ballast, it provides a good mat to distribute loads from the ballast and prevents ballast particles from being pushed into the subgrade. A sub-ballast layer is required whenever:

a. The subgrade contains 85 percent or more (by weight) of silt and clay sized particles, or
b. The subgrade material has a liquid limit greater than 50 and a plasticity index greater than 20.

5-13.3 Material.

Sub-ballast should be a hard, angular, non-cementing material. Aggregate base courses specified by the local state department of transportation are typically good sub-ballast materials and can be considered for use.

5-13.4 Gradation.

Filter layers consist of sub-ballast particles ranging in size from the smallest ballast particles to the largest subgrade particles. Specifying ASTM D1241 Type I, Gradation B or the somewhat finer Gradation C provides an appropriate gradation. Also, aggregate base courses specified by the local state department of transportation typically have appropriate gradations. One of the following gradations must be met if a local aggregate base course material is used:

Table 5-12 Gradations

<table>
<tr><th colspan="2">Sieve Size</th><th>1 in.
(25 mm)</th><th>⅜ in.
(9.5 mm)</th><th>No.4
(4.75 mm)</th><th>No. 40
(425 μm)</th><th>No. 200
(75 μm)</th></tr>
<tr><td rowspan="2">Percent Passing</td><td>Gradation 1</td><td>70-100</td><td>35-75</td><td>25-65</td><td>5-30</td><td>5-15</td></tr>
<tr><td>Gradation 2</td><td>90-100</td><td>50-85</td><td>35-65</td><td>10-35</td><td>5-15</td></tr>
</table>

In addition, the materials must meet the following physical requirements:

- Coarse aggregate (that portion retained on the No. 4 (4.75 mm) sieve) composed entirely of crushed stone or crushed aggregate.
- The maximum percent of wear for the coarse aggregate fraction (that portion retained on the No. 4 (4.75 mm) sieve) is 50 percent when tested per ASTM C131.
- For the fraction passing the No. 40 (425 µm) sieve, the maximum liquid limit is 25 and the maximum plasticity index is 6.

5-13.5 Depth.

The sum of the sub-ballast depth and the ballast depth is often referred to as the total ballast depth. When sub-ballast is used, substitute sub-ballast material for a portion of the total ballast depth determined by structural analysis on a one-for-one basis.

A sub-ballast layer can comprise up to 40 percent of the total ballast depth on main running tracks and up to 50 percent on auxiliary and terminal tracks. When used, the minimum sub-ballast thickness will be 4 in. (101 mm) with a minimum ballast thickness of 6 in. (152 mm), resulting in a minimum total ballast depth of 10 in. (254 mm).

5-14 TIES AND TIE SPACING.

5-14.1 Wood Ties.

In most cases, wood is still the most cost-effective tie material. Required specifications for wood ties are found in Chapter 30, Part 3 of the AREMA Manual. The recommended species of wood for cross ties are:

Table 5-13 Recommended Wood Species for Cross Ties

Hardwoods	Softwoods
Ash	Douglas Fir
Beech	Pine
Hickory	Spruce
Red Oak	
White Oak	

Strictly defined, hardwood and softwood refer to a type of tree and not the hardness or density of the wood. However, the hardwoods listed above are denser and generally more durable than the listed softwoods and thus usually more desirable for ties. While softwoods are sometimes preferred on open deck bridges to help absorb impact, they are not recommended for use in turnouts or in curves over 8 degrees where the better spike-holding ability of the denser woods is needed.

5-14.1.1 Species.

Hardwood ties are often sold in species groups such as mixed hardwoods or oak. The mixed hardwoods can comprise, for example, 40 percent oak and 60 percent assorted hardwoods, including gum. Gum is not a preferred species but is commonly used. The oak group is usually a mix of red and white oak and typically costs more than the mixed hardwoods. The use of either mixed hardwood group or oak group ties is acceptable for military installations.

For track with annual traffic volumes of 5 million gross tons (4.5 Metric tons) or less, as is common at military installations, wood ties are more likely to fail from decay rather than mechanical wear or loss of spike-holding ability. Use information from the engineering department of the serving commercial railroad, regional tie suppliers, and local experience to select the most appropriate ties.

5-14.1.2 Cross-Section and Length.

The two common cross-sectional sizes for wood track ties are 7 in. (178 mm) thick by 9 in. (229 mm) wide or 6 in. (152 mm) thick by 8 in. (203 mm) wide. 7x9 (178x229) ties are recommended for areas with higher traffic volumes and wheel loads as well as in turnouts and in road crossings.

Track ties are commonly produced in 8.5 or 9 ft (2.6 or 2.75 m) lengths. Use minimum 8.5-ft (2.6 m) length ties, except for road crossing and turnouts. 10-ft. or 9-ft. (3 m or 3.75 m) long ties are typically used in road crossings. Ties for turnouts vary from 9 to 17 ft (2.75 to 5.2 m) long as indicated in Table 5-14.

Table 5-14 Switch Ties for Standard Turnouts

Frog #	Switch Point Length ft (m)	Lead Distance	Number of Ties of Each Length									Total Ties
			9 ft (2.74m)	10 ft (3.05m)	11 ft (3.35m)	12 ft (3.66m)	13 ft (3.96m)	14 ft (4.27m)	15 ft (4.57m)	16 ft (4.88m)	17 ft (5.18m)	
8	16½ (5.03)	68 ft (20.3 m)	7	13	6	6	4	5	7	6	3	57
9	16½ (5.03)	72 ft-3.5 in. (22 m)	7	13	7	7	6	5	8	6	4	63
10	16½ (5.03)	78 ft-9 in. (24 m)	7	15	8	7	6	6	7	8	4	68

Note: Each tie set includes 2 - 15 ft. (4.6 m) ties for head blocks, which hold the switch stand.

5-14.1.3 Treatment.

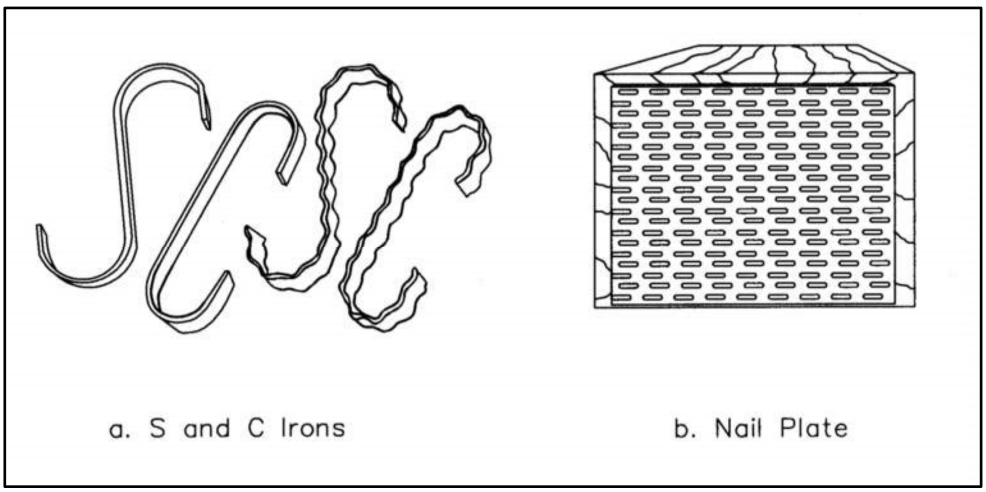
All wood ties will be pressure treated with preservative as specified in AWPA Standard U1, Commodity Specification C, to the requirements of Use category 4 (UC4). The preferred preservative for ties is a creosote solution (CR-S) as specified in AWPA Standard P2. For ties used west of the Mississippi River, a creosote-petroleum solution (CR-PS) as specified by AWPA Standard P3 is used.

In areas of high decay from fungi, insects or severe climactic or exposure conditions, a dual treatment with borate and creosote is recommended to significantly extend tie life. Dual treatment with borate (SBX) is specified in AWPA Standard P25. The average life expectancy of a properly treated wood tie in the CONUS is 25 to 35 years. The life expectancy in high-decay regions of the CONUS is as low as 12 years.

5-14.1.4 Anti-Splitting Devices.

To reduce the tendency of wood to split, anti-splitting devices are often applied to the ends of ties. Anti-splitting devices are recommended for turnout ties but can be specified for standard track ties. Of the two general types, as shown in Figure 5-21, the nail plates are more effective and thus preferred.

Figure 5-21 Anti-Splitting Devices for Tie Ends



5-14.1.5 Pre-Boring.

Once a common practice, the pre-boring of spike holes is no longer recommended.

5-14.1.6 Tie Spacing.

The center-to-center distance between adjacent ties ranges from 19.5 to 22 in. (495 to 558 mm), with a minimum allowable of 18 in. (460 mm) and a maximum of 24 in. (609 mm). For auxiliary and loading tracks, a 21 to 23-in. (533 to 584 mm) spacing is typical. Specify tie spacing after a structural analysis has been performed.

5-14.1.7 Pros and Cons.

The advantages of wood ties include:

- Typically, the most economical tie.
- Are widely available in the CONUS from many suppliers.
- Utilize typical hardware and equipment to attach the rail.
- Can be used in all track situations.
- Are good at surviving derailments.

The disadvantages of wood ties include:

- Short service life in high-decay environments.
- Typically require the use of rail anchors.
- Environmental issues associated with the disposal of defective ties.
- The track gage must be set manually by measuring prior to spiking the rail.

5-14.2 Engineered Composite Ties.

Engineered composite ties are composed of two or more materials in a matrix binder. The components can include recycled materials. Since the matrix often includes plastic, engineered composite ties are often referred to as plastic ties. Engineered composite ties are not widely used, but they have been used at DoD installations in high-decay areas of the CONUS. Due to their resistance to decay, they are well-suited to use in road crossings. They use the same hardware and equipment to attach the rail as is used with wood ties. To increase lateral and longitudinal track stability, engineered composite ties are typically manufactured with surface patterns to mechanically interlock with the ballast. Ensure engineered composite ties conform with the specifications in Chapter 30, Part 5 of the AREMA Manual.

5-14.2.1 Cross-Section and Length.

Engineered composite ties are typically 7 in. (178 mm) thick by 9 in. (229 mm) wide. The length of regular ties is typically 9 ft (2.75 m). Longer lengths are available for use under road crossings and as switch ties in turnouts. Since their dimensions are the same as typical wood ties, they are used to replace wood ties without other modifications to the track.

5-14.2.2 Pre-boring.

Engineered composite tie manufacturers typically recommend pre-boring of spike holes.

5-14.2.3 Tie Spacing.

The spacing for engineered composite ties is the same as for wood ties, usually ranging from 19.5 to 22 in. (495 to 558 mm), with a minimum allowable of 18 in. (460 mm) and maximum of 24 in (609 mm).

5-14.2.4 Pros and Cons.

The advantages of engineered composite ties include:

- Are resistant to decay.
- Have an estimated life span of 50 years.
- Are well-suited for use in road crossings.
- Can be intermixed with wood ties.
- Use the same hardware and equipment to attach the rail as wood ties.
- Can be used in all track situations.
- Defective ties may be recyclable.

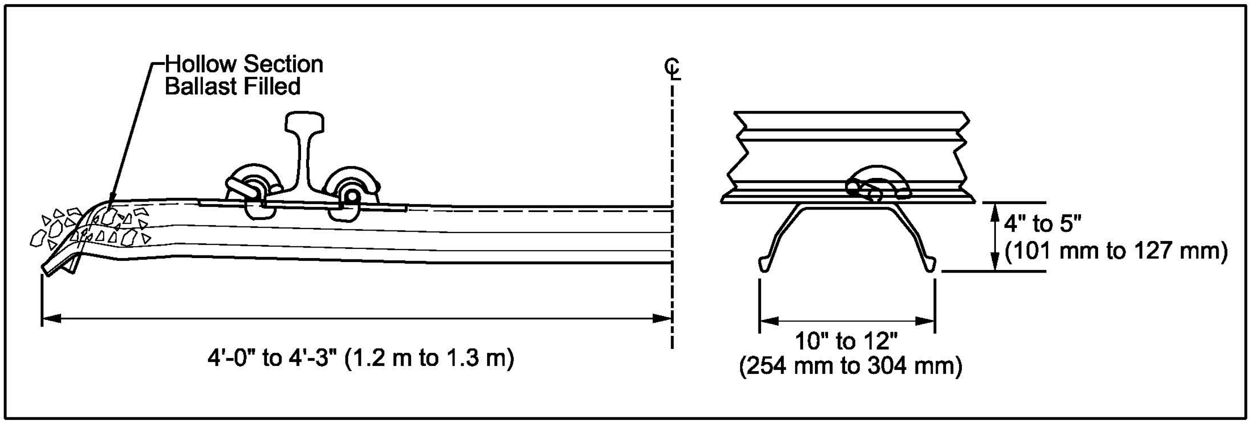
The disadvantages of engineered composite ties include:

- Are more expensive than wood ties.
- There are a limited number of suppliers in the CONUS.
- Are not good at surviving derailments.
- Typically require the use of rail anchors.
- The track gage must be set manually by measuring prior to pre-boring and spiking the rail.

5-14.3 Steel Ties.

The use of steel ties in the CONUS is increasing, particularly in yards, low-speed tracks, and tunnels. Steel ties consist of a hollow shell with an inverted U-shaped cross section as shown in Figure 5-22. The hollow shell is packed with ballast to ensure the bearing area is at the top of the inside shell rather than at the bottom of the tie. This allows for reduced overall ballast thickness, which can make steel ties more economical than wood ties for new track construction in areas where ballast material cost is high. A minimum thickness of 10 in. (254 mm) of ballast, measured from the top of the tie, is required. Place a minimum 4 in. (101 mm) thickness of sub-ballast beneath the ballast. Inspection holes located in the steel tie’s top surface allow for visual inspection that the hollow underside has been completely filled and proper ballast tamping has been achieved. Since the sides of the tie are embedded in the ballast, steel ties provide good longitudinal and lateral support of the track. Ensure steel ties conform with the specifications in Chapter 30, Part 6 of the AREMA Manual.

Figure 5-22 Steel Tie



5-14.3.1 Tamping.

Extra care is required when tamping steel ties. Since steel ties are not as tall as wooden ties, reduce the embedment depth of the tamper machine tools to match. Otherwise, proper compaction of the ballast under the steel ties will not be achieved. When steel ties are interspersed with wood ties, it is necessary to make two passes with the tamper: one pass with the tamper machine tools set at the proper depth for wood ties and a second pass to tamp the steel ties with the tamper machine tools set at the reduced insertion depth.

5-14.3.2 Fastening.

Steel ties utilize steel spring clips to attach the rail to the tie. This system tightly clamps the rail to the tie and eliminates the need for tie plates, spikes, and rail anchors. The ties are pre-punched for the fasteners, so track gage is set at the factory. In signalized track and near signalized road crossings, insulators are placed underneath the rail base and between the spring clips and the rail to prevent the steel tie from shunting the electric current between the rails.

The tension strength of the steel material and clamping action of the spring clips result in greater strength to hold gage than other ties. Because of this, steel ties are sometimes interspersed with wood ties (for example, every fifth tie is steel) in sharp curves and other areas where gage widening is a problem.

5-14.3.3 Road Crossings.

When steel ties are placed under a road crossing, the road crossing must be an asphalt crossing with rubber interface. If a different type of crossing is desired or required, use wood or engineered composite ties through the length of the crossing with a transition back to steel ties outside the limits of the crossing. A transition to a different type of tie must be used under roads that will carry tracked vehicles.

5-14.3.4 Turnouts.

Steel switch ties are available for use in turnouts. However, do not intersperse steel switch ties with other types of switch ties in a turnout. Do not use steel ties as the primary tie in track with speeds above 25 mph (40.2 km/hr) since the higher dynamic forces coupled with the stiffness of the steel can accelerate degradation of the ballast. However, it is acceptable to intersperse steel ties with wood ties (for example, every fifth tie is steel) in track with speeds greater than 25 mph (40.2 km/hr).

Steel ties are made of a special type of steel that acquires an initial coating of rust-like oxide that protects the steel from further corrosion. Steel ties are also very resistant to biological decay.

5-14.3.5 Cross Section and Length.

Steel ties are typically wider, but not as deep as wood ties. They can be shorter than wood ties. Typical dimensions of steel ties are shown in Figure 5-22. Longer lengths are available for use in turnouts. The length of switch ties in turnouts varies between manufacturers and will likely vary from the lengths shown in Table 5-14.

5-14.3.6 Tie Spacing.

The typical spacing for steel ties ranges from 20 to 24 in. (508 to 609 mm).

5-14.3.7 Pros and Cons.

The advantages of steel ties include:

- Requires less ballast since the required depth of ballast is measured from the top of the tie rather than the bottom of the tie.
- More economical than wood ties for new track construction in regions where ballast material cost is high.
- Cost effective in certain OCONUS situations with limited access to wood ties.
- Can be compactly stacked like plastic cups to minimize volume for shipping.
- Are resistant to decay.
- Have an estimated lifespan of 50 years or more.
- Can be intermixed with wood ties in existing track.
- Spring clip attachment system eliminates the need for tie plates and rail anchors.
- Spring clips do not loosen over time as occurs with spikes in wood ties.
- Track gage is set at the factory, reducing the chance of improper track gage during installation.

- Are superior to wood and engineered composite ties at holding gage.
- Are good at surviving derailments.
- Defective ties are recyclable.
- Are lightweight, which facilitates handling.

The disadvantages of steel ties include:

- Are more expensive than wood ties when replacing ties in existing track.
- Requires adjustment of the tamping machine tools for less depth compared to wood and engineered composite ties.
- Requires two passes of a tamping machine during surfacing operations when steel ties are interspersed with wood ties.
- Requires extra care during tamping operations to ensure the hollow underside has been completely filled with ballast.
- Should not be used for tracks with speeds greater than 25 mph (40.2 km/hr).
- There is a limited number of suppliers in the CONUS.

5-14.4 Concrete Ties.

Concrete ties are used by some commercial railroads, particularly on lines with the heaviest traffic volumes and in areas with numerous curves. Where used, concrete ties are in track with welded rail and solidly supported with deep ballast sections. Concrete ties are usually not economical on lighter traffic lines and are usually not suitable for use with jointed rail or in track of lighter construction. Also, concrete ties cannot be successfully mixed with wood ties. Thus, concrete ties are not economical and are not recommended for general use in CONUS military track. The use of concrete ties for certain OCONUS applications can be cost effective. These applications include areas where concrete ties are in widespread use and where timber is in short supply. Prior to selecting concrete ties for an installation, conduct an economic analysis.

Concrete ties are prestressed concrete. Wire reinforcement provides the prestressing force, keeping the concrete in compression to prevent cracking. The reinforcement also provides bending strength.

5-14.4.1 Fastening.

Concrete ties utilize steel spring clips to attach the rail to the tie, similar to steel ties. However, a specialized pad must be placed between the base of the rail and the tie. The pad cushions the load, preventing the development of rail and track surface defects. Steel shoulder inserts are cast into the tie to accept the spring clips. This results in the track gage being set at the factory. Insulators are placed between the steel shoulder inserts and the rail base and between the spring clips and the rail to isolate the tie electrically.

5-14.4.2 Road Crossing.

Concrete ties are available for road crossings and for use as switch ties in turnouts. However, the CONUS commercial railroads typically do not use concrete ties in road crossings or in turnouts. Instead, they transition to wood ties and use them throughout the limits of road crossings and turnouts.

5-14.4.3 Subgrade.

Subgrade cross slope must be constant under the length of a concrete tie. Do not locate a subgrade or sub-ballast crown below a concrete tie to avoid over-stressing the tie during ballast placement and tamping.

5-14.4.4 Cross Section and Length.

Concrete ties are typically 10 to 11in. (254 to 279 mm) wide at their base and taper to 7 to 8 in. (178 to 203 mm) wide at the top. The height is typically 8 to 8.5 in. (203 to 216 mm) at the ends of the ties and transitions to 6 to 6.5 in. (152 to 165 mm) between the rails. The typical length of a concrete tie in CONUS is 8 ft.-3in. (2.5 m). The dimensions of concrete ties in OCONUS locations can vary.

5-14.4.5 Tie Spacing.

The typical spacing for concrete ties is 24 in. (609 mm).

5-14.4.6 Pros and Cons.

The advantages of concrete ties include:

- Cost effective in certain OCONUS situations with limited access to wood ties.
- Resistant to decay.
- Have an estimated lifespan of 50 years.
- Spring clip fastening system eliminates the need for tie plates and rail anchors.
- Track gage is set at the factory, reducing the chance of improper track gage during installation.
- Are superior to wood and engineered composite ties at holding gage.

The disadvantages of concrete ties include:

- Are not economical and not recommended for general use in CONUS military track.
- Should not be used with jointed rail.
- Require a thicker ballast section.

- Cannot be intermixed with wood ties.
- Typically requires a transition to wood ties through the limits of road crossings and turnouts in CONUS situations.
- Are not good at surviving derailments.
- Concrete ties are approximately three times heavier than wood.

5-15 RAIL.

5-15.1 Section Designation.

Rail is rolled into different sizes (dimensions) and shapes commonly referred to as "weight" and "section." The weight of a rail is based on how much a rail weighs in pounds per yard of length. The section refers to the cross-sectional shape of the rail.

5-15.2 Selection Criteria.

Perform a structural analysis prior to selection of a rail section. Consider structural requirements, as well as cost and availability of rail sections before making a final selection.

5-15.3 Recommended New Rail Sections.

Weights and sections recommended for new rail purchases are: 115RE and 136RE, with 115RE being the preferred. These are the standard sections recommended by the AREMA.

Rail is purchased in 39- or 80-ft (11.9 or 24.4 m) lengths. Rail 80 ft. (24.4 m) long has the advantage of reducing the number of joints to half that for 39 ft. (11.9 m) rail. For small purchases where the rail is transported by truck, 39 ft. (11.9 m) lengths are more cost effective.

5-15.4 Relay (Secondhand) Rail.

Secondhand rail meeting the specifications in Table 5-15 either as is or after cropping off the ends, can be used for rehabilitation or new construction. Investigate the cost, condition, and availability of matching joint bars and tie plates before selecting relay rail.

Recommended relay rail sections are: 115RE, 132RE, 133RE, and 136RE. Select relay rail to limit the number of different rail weights and sections within the track network. Ensure the section and joint drilling pattern (bolt hole size and spacing) are consistent for a given weight. Due to the varying market for relay rail, recommend allowing the contractor an option to provide an acceptable rail section. Limit selection to sections that are sufficiently plentiful to supply future maintenance purchase requirements: rail, joint bars, frogs and other turnout parts.

5-15.5 Lightweight Rail.

Lightweight rail weighs less than 90 lb. per yd (44.6 kg/m). These weights are no longer manufactured and are only available as secondhand.

Do not use rail weights less than 90 lb. per yd (44.6 kg/m). A structural evaluation is necessary to determine the adequacy of these rail weights. Replace rail not adequate to support the desired wheel loads.

5-15.6 Continuous Welded Rail (CWR).

Continuous welded rail (CWR) is strings of standard rail welded together either in a rail plant or by field welding after installation. CWR is commonly used on commercial railroads and is beneficial in reducing maintenance costs due to rail joints. CWR is not recommended for general use on military track because it:

1. Requires a larger ballast section to provide sufficient track restraint
2. Needs more rail anchors to restrain longitudinal rail expansion
3. Is more subject to buckling in hotter weather and pull-aparts during colder weather
4. Has a higher initial installation cost

If conveniently available, short strings (less than 200 ft. (61 m)) are appropriate for wide road crossings or track in paved areas. CWR is applicable on certain lines that form a long connection to the serving commercial railroad. See Chapter 5, Section 3.1 of the AREMA Manual for additional CWR information.

5-15.7 Field Welds.

Weld rail running through road crossings and for 20 ft. (6 m) on either side of crossings to eliminate joints in these areas. Consider field welding for rail placed in confined loading areas, adjacent to warehouse loading docks, and in other areas where maintenance access to rail joints is difficult.

Accomplish rail welding with special thermite welding kits designed for this purpose and by people with the necessary training and experience in welding rail. Where many welds are performed, some specialized contractors have truck-mounted electric welding units designed for this purpose.

5-15.8 Salvaging Rail.

During track reconstruction, the existing rail and other track materials can often be salvaged for use at other locations on the installation, stockpiled for future construction projects, or sold on the open market as used material. Dispose of lightweight rail, defective rail, and other track materials not suitable for use in track reconstruction or for resale on the open market as scrap or reroll material.

Table 5-15 Dimension and Surface Specifications for Relay (Secondhand) Rail

Length	For Standard 39 ft (11.9 m) lengths: Not more than 10% of lot between 33 ft and 39 ft. (10.1 m to 11.9 m). No rail shorter than 33 ft. (10.1 m).
Vertical Wear	90 lb (44.6 kg) or Larger: Average top wear 5/16 in. (7.9 mm) or less with maximum at any one location of 11/32 in. (8.7 mm)
Side Wear	At least one side must meet the following: 90 lb (44.6 kg) or Larger - Maximum of 5/16 in. (7.9 mm)
Lip or Overflow	Maximum of 1/16 in. (0.8 mm), either as is or obtained by grinding off excess.
Engine Burns	Maximum of 1/2 in. (13 mm) diameter (or 1/4 in. (6.4 mm) wide by 1/2 in. (13 mm) long) and 1/32 in. (0.8 mm) deep. Maximum of four engine burns per rail. Engine burns on no more than 8% of the lot.
End Batter And Chipping	Maximum of 1/8 in. (3.2 mm) when measured 1/2 in. (13 mm) from the rail end with an 18 in. (460 mm) straightedge.
Running Surface Damage	Maximum size of 1/4 in. (6.4 mm) wide by 1/2 in. (13 mm) long and 1/32 in. (0.8 mm) deep. Maximum of four damaged spots in any one rail.
Defects Not Permitted	Bolt hole cracks or breaks, broken base, crushed head, detail or engine burn fractures, head-web or web-base separations, piping, horizontal or vertical split head or web, torch cuts or flame gouges, compound or transverse fissures, deep pitting from corrosion.
Condition and Appearance	Rail must be: free from obvious defects; clean in appearance; straight in line and surface and without kinks; and free from base defects such as plate wear and spike notches.
Internal Inspection	Rail to be ultrasonically inspected before or after installation. Defective sections to be rejected and replaced.
Note: See AREMA Manual Chapter 4, Part 4 for rail defect definitions and illustrations.	

5-16 OTHER TRACK MATERIAL.

5-16.1 Definition.

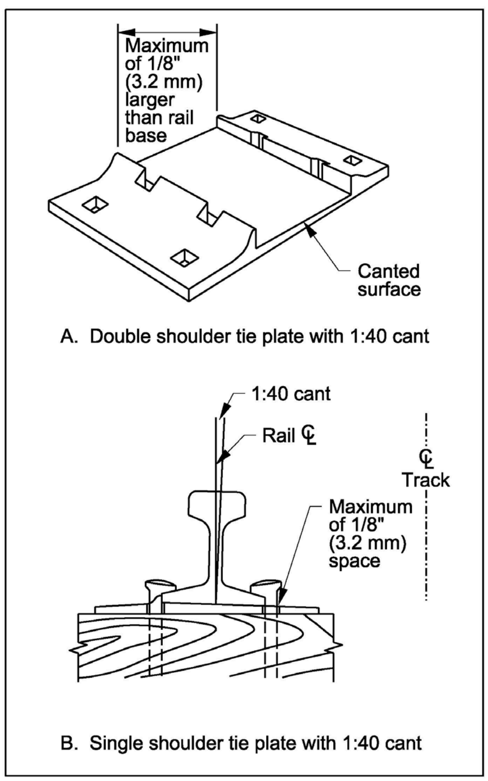
Tie plates, joint bars, bolts, spikes and other miscellaneous hardware used in track construction are commonly referred to as other track materials (OTM).

5-16.2 Tie Plates.

Tie plates vary in length and width. Most sizes are suitable, as long as the spike hole punching (or distance between the shoulders - for double shoulder plates) matches the width of the rail base. For double shoulder tie plates, the distance between the shoulders will be at most 1/8 in. larger than the rail base width. On single shoulder plates, the spike holes on the gage side (opposite the shoulder) must keep the inside face of the spike within 1/8 in. of the rail base when the opposite edge of the base is against the shoulder. See Figures 5-23 (a) and (b).

Use either single or double shoulder tie plates. Single shoulder tie plates are no longer manufactured. Only relay/secondhand single shoulder tie plates are available. Within a given length of track, it is allowable to use tie plates of different lengths and widths, and single shoulder plates can mix with double shoulder plates. However, do not mix plates with different cants: those with level rail seats and those with a 1:40 slope. Tie plates with a 1:40 cant are preferred. Secondhand plates that are not bent, have not lost much material due to corrosion, and otherwise meet the above requirements, are acceptable.

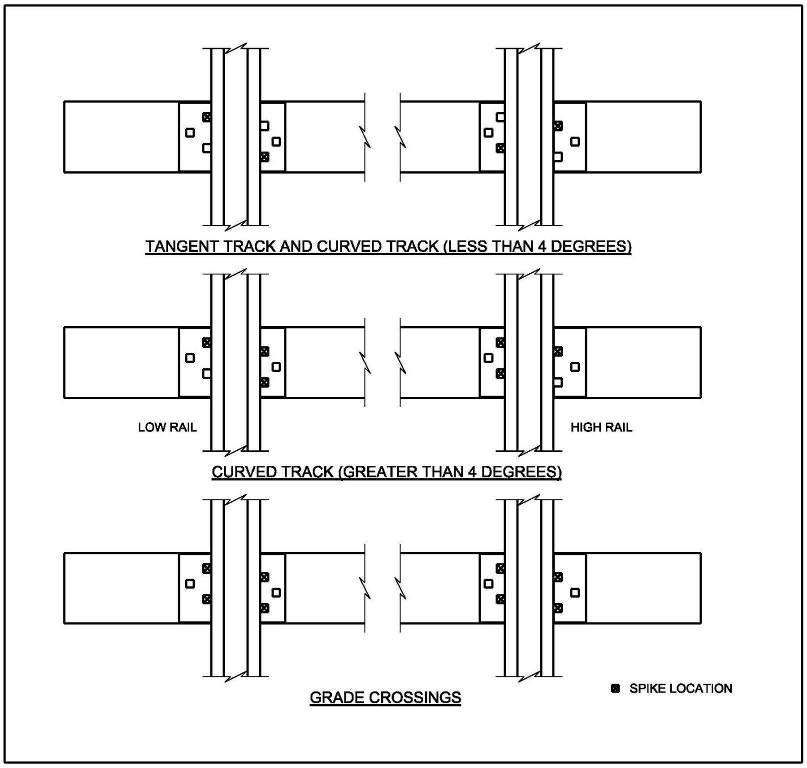
Figure 5-23 Tie Plates



5-16.3 Spikes.

On tangent track and on curves up to 4 degrees, use one spike on the gage and field side of each rail, for a total of four spikes in each tie. On curves greater than 4 degrees, use one spike on the field side and two spikes on the gage side of each rail, for a total of six spikes in each tie. On track within road crossings, use two spikes on the gage side and two on the field side of each rail, for a total of eight spikes in each tie. Diagrams of these spiking patterns are shown in Figure 5-24.

Figure 5-24 Typical Spiking Plans



5-16.4 Rail Spring Clips.

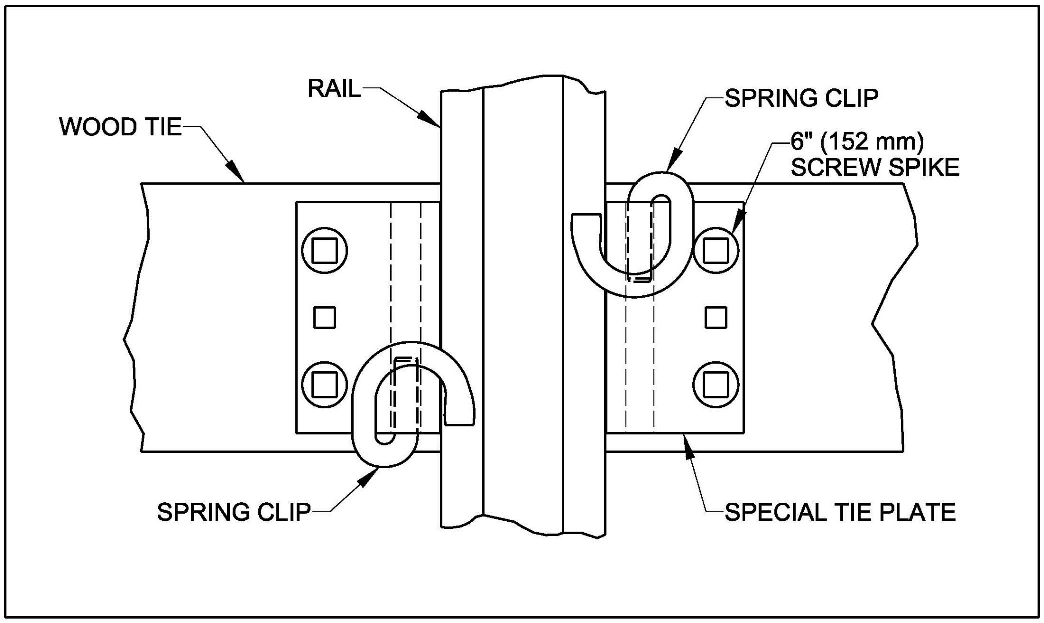
Rail spring clips are elastic forged steel fasteners that attach the rail base to steel or concrete ties to prevent horizontal and vertical movement of the rail. Rail spring clips can also be used with wood and engineered composite ties with special tie plates. Use rail spring clips with wood and engineered composite ties in situations where difficulty in holding gage is anticipated or encountered, such as curves sharper than 8 degrees. The spring clips come in different configurations. A common type of spring clip on a wood tie is shown in Figure 5-25. The spring clips tightly clamp the base of the rail to the tie and are typically applied and removed with a sledge hammer or special mechanized equipment. Spring clips eliminate the need for rail anchors.

5-16.5 Rail Joints and Joint Bars.

Use either four-hole (24-in. (608 mm)) or six-hole (36-in. (914 mm)) joint bars for rail joints. Standard joint bars are used to join rail of the same section. Compromise joint bars are used to join rail of different section. Ensure both standard and compromise joint bars are properly factory designed and constructed. In addition, ensure the bars are of the size, shape, and punching pattern to fit the rail being joined. Specifications for new joint bars are found in “Specifications for Quenched Carbon Steel Joint Bars and Forged Compromise Joint Bars" in Chapter 4, Part 3 of the AREMA Manual and joint bar assemblies in Chapter 4, Part 3 of the AREMA manual. Compromise joints will be specified as indicated in AREMA Portfolio of Trackwork Plan 700B.

Use secondhand joint bars on secondhand rail if not bent, cracked, excessively corroded, or otherwise defective. Do not use secondhand joint bars on new rail. Use either field-applied type or prefabricated (glued) type joints for insulated joints required to isolate signal currents for road crossing warning devices. Special insulated tie plates are also required. It is recommended that rail joints be welded where located in paved areas or at any location where access to the joint is restricted.

Figure 5-25 Typical Rail Spring Clip



5-16.6 Track Bolts, Nuts, and Spring Washers.

Track bolts, nuts, and spring washers will conform to the specifications in Chapter 4, Part 3, of the AREMA Manual.

Common bolt diameters for different rail weights are found in Table 5-16.

Table 5-16 Common Joint Bolt Diameters

Bolt Diameter - in. (mm)	Rail Weights - lb/yd (kg/m)
1 (25)	90 to 130 (44.6 to 64.5)
1⅛ (25.4)	131 to 140 (65 to 69.4)

5-16.7 Rail Anchors.

For new construction, as a minimum, use rail anchors on main running tracks with spikes to restrain longitudinal rail movement in the quantity and arrangement diagrammed in Figure 5-26. Use additional anchors on track with grades steeper than 0.5 percent if required, and where maintenance problems indicate a need. Rail anchors are required in track with continuous welded rail. Rail anchors are not necessary in tracks that utilize rail spring clips. When anchors are used, apply four anchors to each tie that is anchored (box anchored), per tie as shown in Figure 5-26.

Use either spring or drive-on type anchors, shown in Figure 5-27. Drive-on anchors have the advantage of being easier to apply and remove manually, and do not require a special anchor wrench, as do spring anchors. Use caution, do not overdrive a drive-on anchor. Overdriving causes the anchor to lose its ability to tightly grip the rail base.

5-16.7.1 Bridges.

Do not use rail anchors across open deck bridges. Instead, box anchor every third tie for two rail lengths off each end of the bridge. Use a similar arrangement at rail crossings, as shown in Figure 5-28. Apply rail anchors at the normal designated pattern across ballast deck bridges.

Figure 5-26 Recommended Minimum Rail Anchor Application

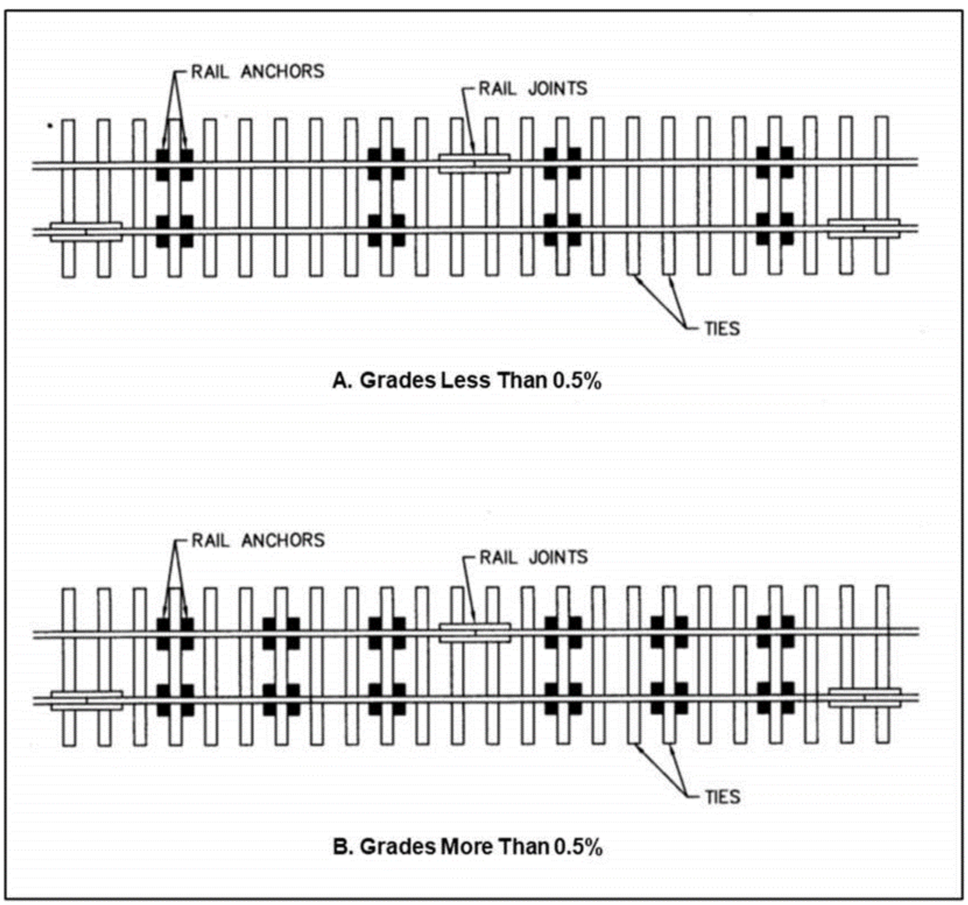


Figure 5-27 Rail Anchors

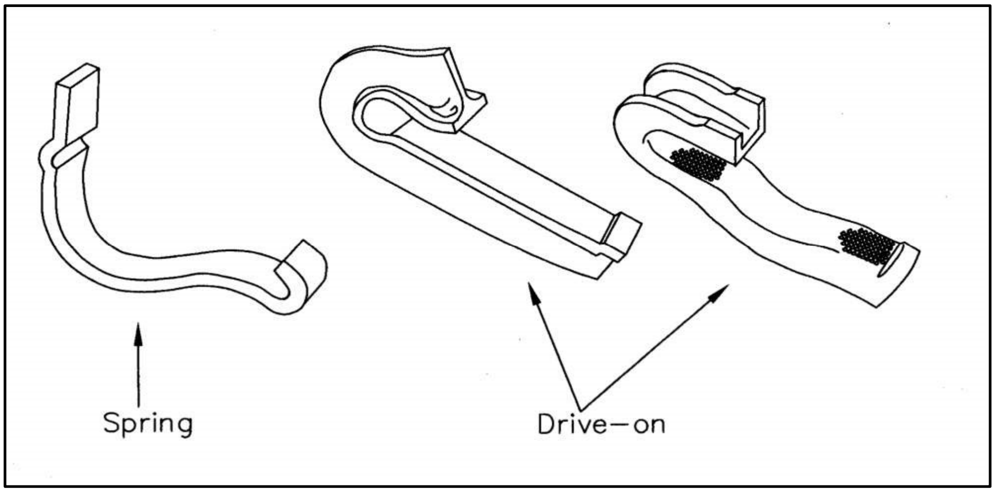
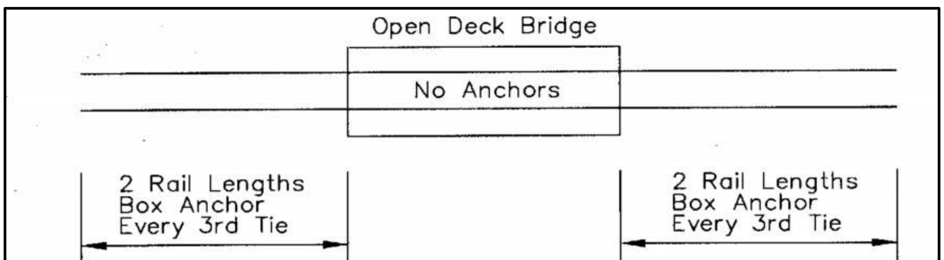


Figure 5-28 Rail Anchor Applications at Open Deck Bridges and Rail Crossings



5-16.8 Gage Rods.

Gage rods are sometimes specified for maintenance purposes on curves over 8 degrees where difficulty in holding gage is encountered. Install two to four rods per rail length when used on sharp curves.

Do not use gage rods for new construction, only use them for maintenance of existing track. In new construction areas where difficulty in holding gage is anticipated, consider the use of wood ties with rail spring clips or steel ties rather than gage rods.

5-17 TURNOUTS AND CROSSOVERS.

Turnouts are designed to divert trains from one track to another. Two turnouts form a crossover when used together to allow the passage of trains between parallel tracks. The general arrangement of turnouts and crossovers is shown in Figure 5-29. The main parts of a turnout are shown in Figure 5-30. For additional switch detail see AREMA Portfolio of Trackwork Plans 190, 220, and 221.

Figure 5-29 General Arrangement of Turnouts and Crossovers

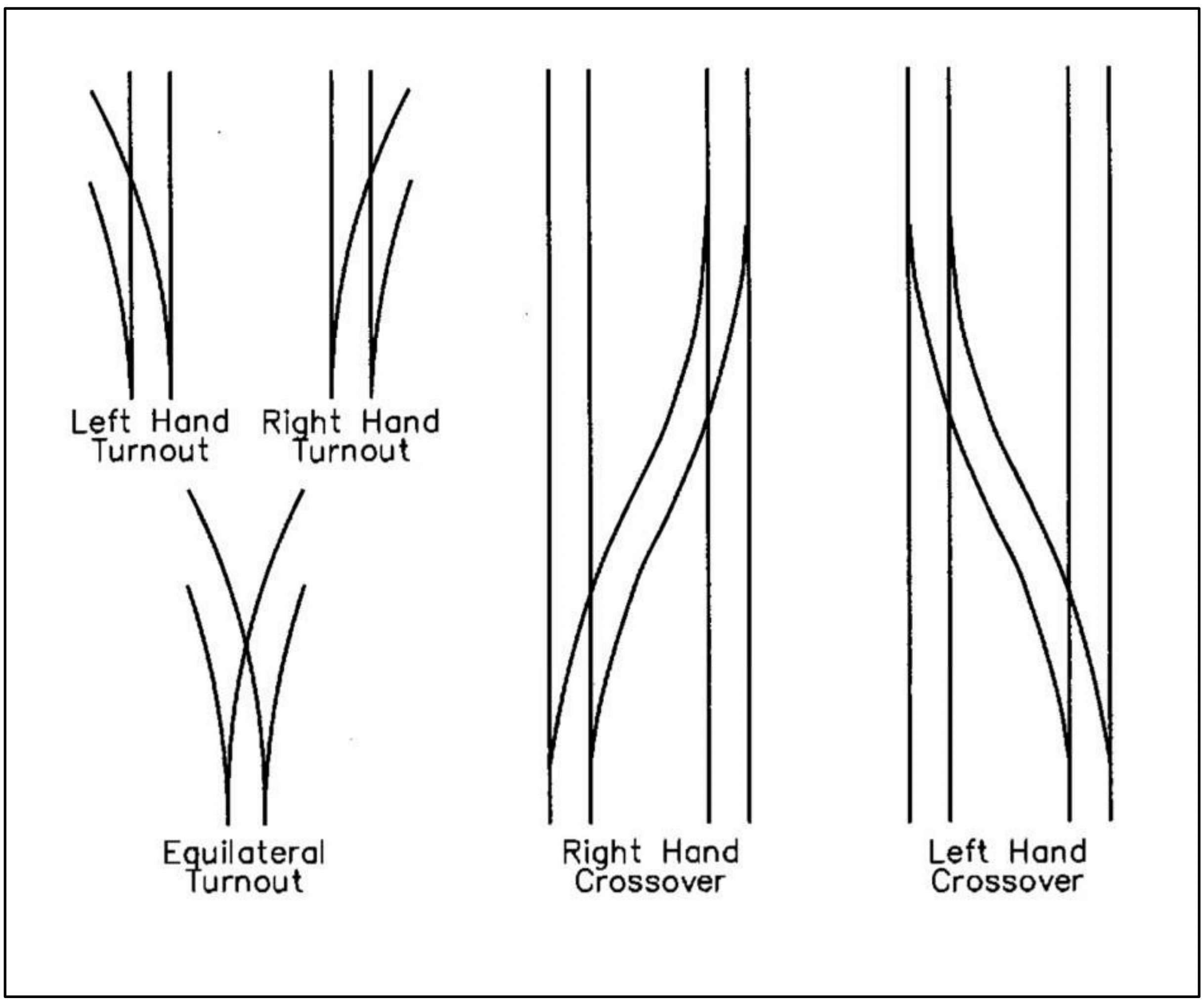
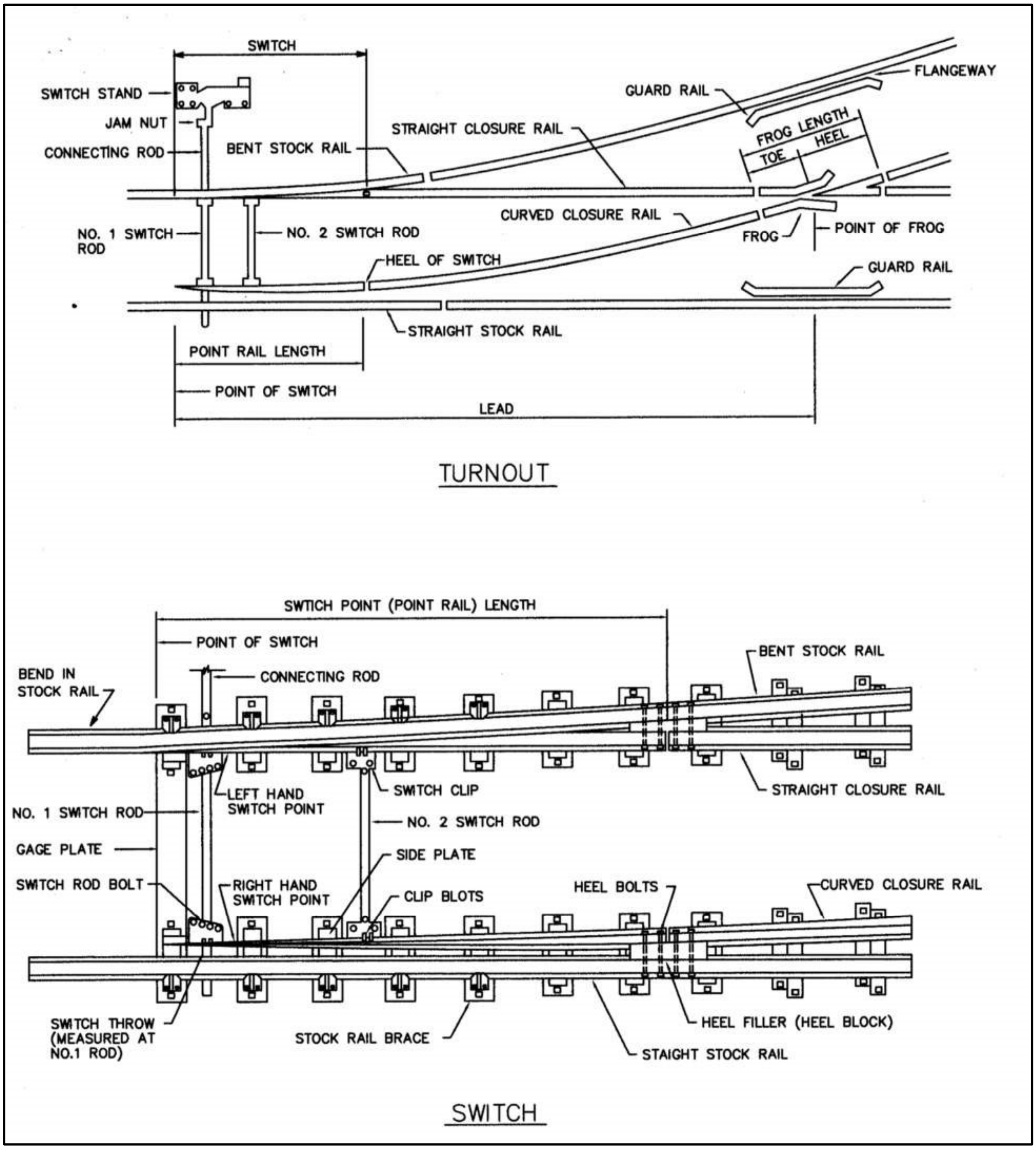


Figure 5-30 Parts of a Turnout



5-17.1 Size.

Turnout size is designated by the size of the frog used in the turnout, as illustrated in Figure 5-31. The size of the frog determines the angle at which the turnout track diverges from the tangent track. Frog size also influences the required degree of curvature within the turnout.

Select standard turnout sizes according to Table 5-17.

Figure 5-31 Determining Frog Number (Turnout Size)

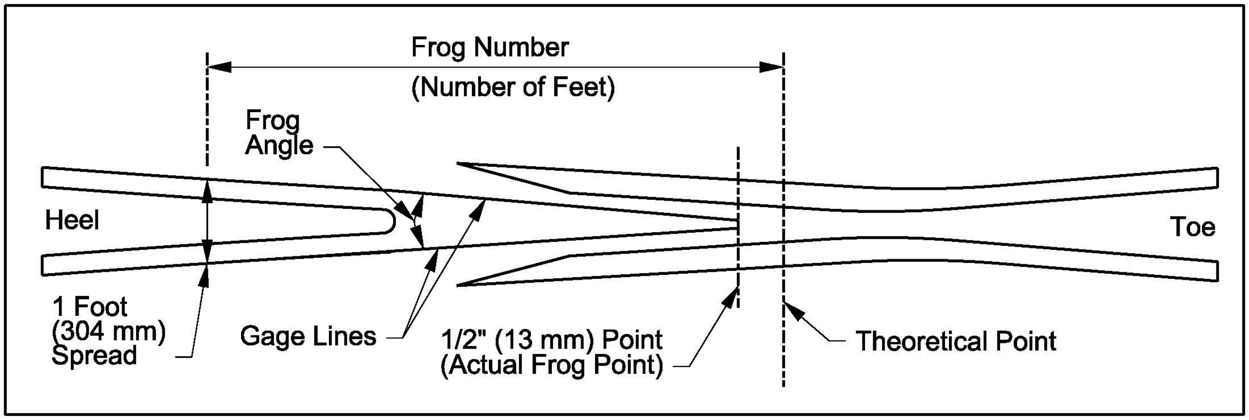


Table 5-17 Turnout Size Selection Criteria

Turnout Size	Turnout Curvature (Degrees)	Selection Criteria
10	7.4	Preferred where space permits, or where long cars (over 75 ft (22.9 m)) or 140-ton (127 MT) flatcars (with 3-axle trucks) are being handled. Use for crossovers.
9	9.3	Smallest size recommended for handling long cars (over 75 ft (22.9 m)) or 140-ton (127 MT) flatcars (with 3-axle trucks). In ladder tracks, saves space compared to a number 10.
8	11.8	Not recommended for handling long cars (over 75 ft (22.9 m)) or 140-ton (127 MT) flatcars (with 3-axle trucks). Smallest size normally permitted.

5-17.2 Design and Selection.

The main design decisions for turnouts are the direction the turnout will diverge, as shown in Figure 5-29, and the angle of the frog (or frog number), which determines how sharply the turnout diverges and also designates the size of the turnout. Recommended choices for different turnout components are covered below, as is layout design for use where nonstandard configurations are required.

Once a standard turnout has been selected from Table 5-17 or the geometry has been otherwise determined, the designer specifies the desired switch, frog, and guard rails if needed, from the appropriate AREMA Portfolio of Trackwork Plans; the turnout or crossover tie set from Table 5-14; and the amount of rail needed to complete the turnout (connect the switch and frog) from AREMA Portfolio of Trackwork Plan 910 or 911. The USACE Omaha District has standard plans available for the turnouts shown in Table 5-14 based on the AREMA Portfolio of Trackwork Plans. Guidance on the selection of these items and other turnout hardware is given below. Ensure all materials used within the limits of a turnout are factory designed and constructed, of the proper type and size, and not flame cut or otherwise altered in the field.

5-17.3 Switch Ties.

A turnout is fastened to a special set of ties called a switch tie set. Generally, switch ties increase in length from the switch point to just past the frog where the turnout ends. From that point, two standard tracks continue. An exception is at the switch point where the switch stand requires two long ties called head blocks to accommodate the stand and operating rods. Determine the make-up of switch tie sets using Table 5-14.

Use 7-in. x 9-in. (178 mm x 229 mm) hardwood ties for turnouts. Use oak switch ties in areas east of the Mississippi River and use oak or Douglas fir in areas west of the Mississippi River. Composite tie and steel tie sets are acceptable in turnouts. Switch tie material and treatment specifications are the same as for standard track ties and are covered in Chapter 5, Paragraph 14.

5-17.4 Switches and Switch Point.

The standard switch for use on military track is the 16 ft., 6-in. (5 m) switch with graduated risers, as shown in AREMA Portfolio of Trackwork Plan 112. The detailed specification for this switch is given in the notes in the upper right corner of the plan. In most cases, the specification will be for a 112A hand throw switch with adjustable braces. Use this specification for switches that are either within or not within a signal circuit (as near crossings with warning lights or gates). Use longer switches as needed when turnouts larger than No. 10 are used.

Specific criteria for switch point design in new turnouts are found in AREMA Portfolio of Trackwork Plan 221, Detail 5100. In locations where traffic conditions cause excessive wear on the tapered ends of the switch point, use manganese steel switch points per AREMA Portfolio of Trackwork Plan 220. The use of spring switches is not recommended on DoD track.

5-17.5 Switch Clips.

Use adjustable ductile iron rocker clips for switch clips as shown in AREMA Portfolio of Trackwork Plan 222, Detail 3117.

5-17.6 Rail Braces.

Use the adjustable type rail braces that support the outside of the stock rails as shown in AREMA Portfolio of Trackwork Plan 224. Leave rigid braces in existing turnouts if they provide adequate support per UFC 4-860-03.

5-17.7 Switch Stands and Lever Latches.

Ergonomic ground throw (low) switch stands are preferred, especially in terminal areas. However, there are situations when the height of the ergonomic stand will conflict with the clearance envelope of an adjacent track. In these situations, use a non-ergonomic stand. Many variations of ergonomic and non-ergonomic stands are available, and most are suitable. Ensure any stand selected has a provision for the throw lever to lock or latch solidly in place. For switches in more remote areas, a switch point lock and/or lever lock is desirable.

5-17.8 Frogs and Guard Rails.

Frogs are secured to ties with universal frog plates as shown in AREMA Portfolio of Trackwork Plan 242 or a set of hook plates. When not using self-guarded frogs, specify guard rails to match the frog size, as listed in Note 2A of AREMA Portfolio of Trackwork Plan 502. Guard rails of the type in AREMA Portfolio of Trackwork Plans 504 or 509 are acceptable.

Do not use spring rail frogs on DoD installations. Bolted rigid frogs that are in existing turnouts and are not defective can stay in place. When new frogs are required, use either solid manganese or rail bound manganese meeting the above specifications.

5-17.8.1 Solid Manganese Self-Guarded.

The solid manganese, self-guarded type frog, as shown in AREMA Portfolio of Trackwork Plans 641 and 691 (Section BB), is preferred for the slower speed operations most common at military installations. Self-guarded frogs simplify turnout construction by not requiring separate guard rails opposite each side of the frog.

5-17.8.2 Railbound Manganese.

Use railbound manganese (RBM) frogs, as shown in AREMA Portfolio of Trackwork Plans 622 - 625, on heavy traffic lines where the traffic is approximately equal on both sides of the frog. This type of frog is most desirable for long turnouts (Size No. 15 or above) since manganese steel is especially suited to the thin long points and requires comparatively little maintenance.

5-17.9 Stock Rails and Closure Rails.

When planning, specify enough rail to make up the straight and curved stock rails and closure rails, as indicated in AREMA Portfolio of Trackwork Plan 910 or 911. This amount will approximately equal twice the actual lead (Column 4) plus the closure distances (Columns 5 and 6). Ensure all rail within the limits of a new or secondhand turnout is of the same weight and section and match the rails on the main and diverging tracks. Compromise joints are not permitted within the limits of a turnout. Where new switch points are specified with relay closure rail, check to assure that the top and gage side of the points and closure rails match at the heel joint.

When rebuilding turnouts, and new and relay rail are available on the project, it is recommended that new rail be used to reconstruct the turnouts; this will avoid the potential problem of rail contour mismatch at the switch heel joints.

5-17.10 Equilateral Turnouts.

In an equilateral turnout, the diverging angle (frog angle) is divided equally on both sides, thus the turnout has two curved stock rails and two curved closure rails that mirror each other. Likewise, the degree of curve along each closure rail is half that of a standard left or right-hand turnout.

5-17.11 Turnouts in Curves.

Do not place turnouts within the limits of horizontal curves without the approval of the AHJ. If a turnout is placed within the limits of a horizontal curve, preferably place the turnout with the curved side of the turnout in the main route's curve and the straight side of the turnout creating the new track to the outside of the curve. In this situation, the curvature of the turnout must match the curvature of the main route curve.

Avoid turnouts creating a new track to the inside of a main route curve. Curvature through a turnout on the inside of a curve equals the degree of curvature for the curve plus that for a standard turnout. Thus, a number 10 turnout off the inside of a 3 degree curve will have a curvature of 3 + 7.4 = 10.4 degrees. Ensure the total curvature does not exceed design limits.

5-18 TRACK CONNECTIONS AND LADDER TRACKS.

5-18.1 Diverging Routes.

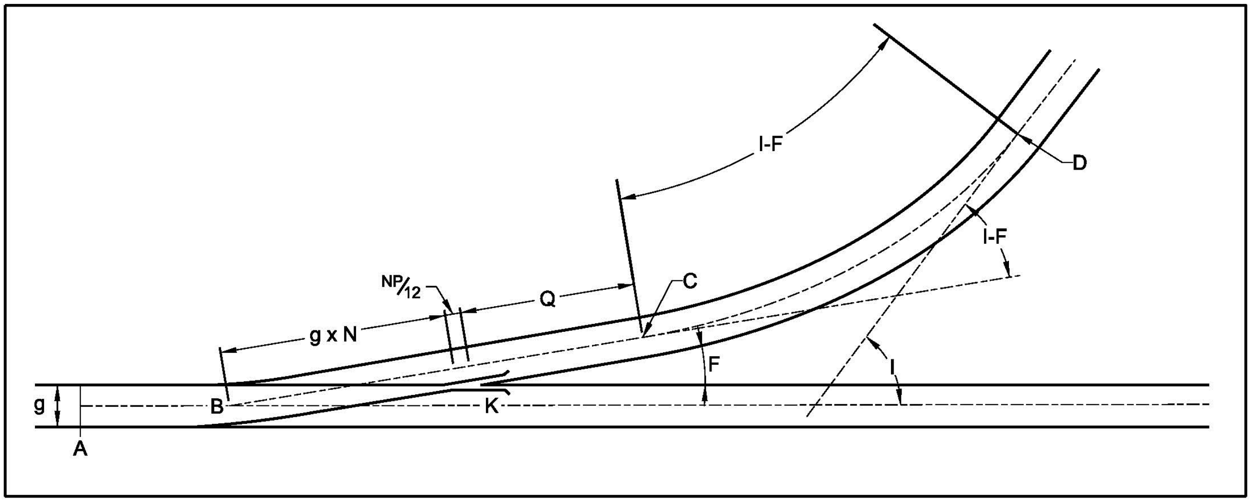
Figure 5-32 shows the layout for a typical diverging route connection. Note that the initial angle that the route diverges is the same as the frog angle for the turnout. If the diverging route needs to be at a different angle, the difference in angle is accomplished with a curve after the turnout and the required tangent distance. The distance from the intersection of track center lines to the location of the frog point is given by Equation 5-13. This distance is critical for determining the location of the turnout.

The layout of a parallel siding connection is a special case of a diverging route. See Figure 5-33. The parallel siding connection is used with sidings and yard ladders.

5-18.2 Crossovers.

Crossovers are a combination of two turnouts used to join two adjacent tracks, as shown in Figure 5-29.

Figure 5-32 Diverging Route Connection

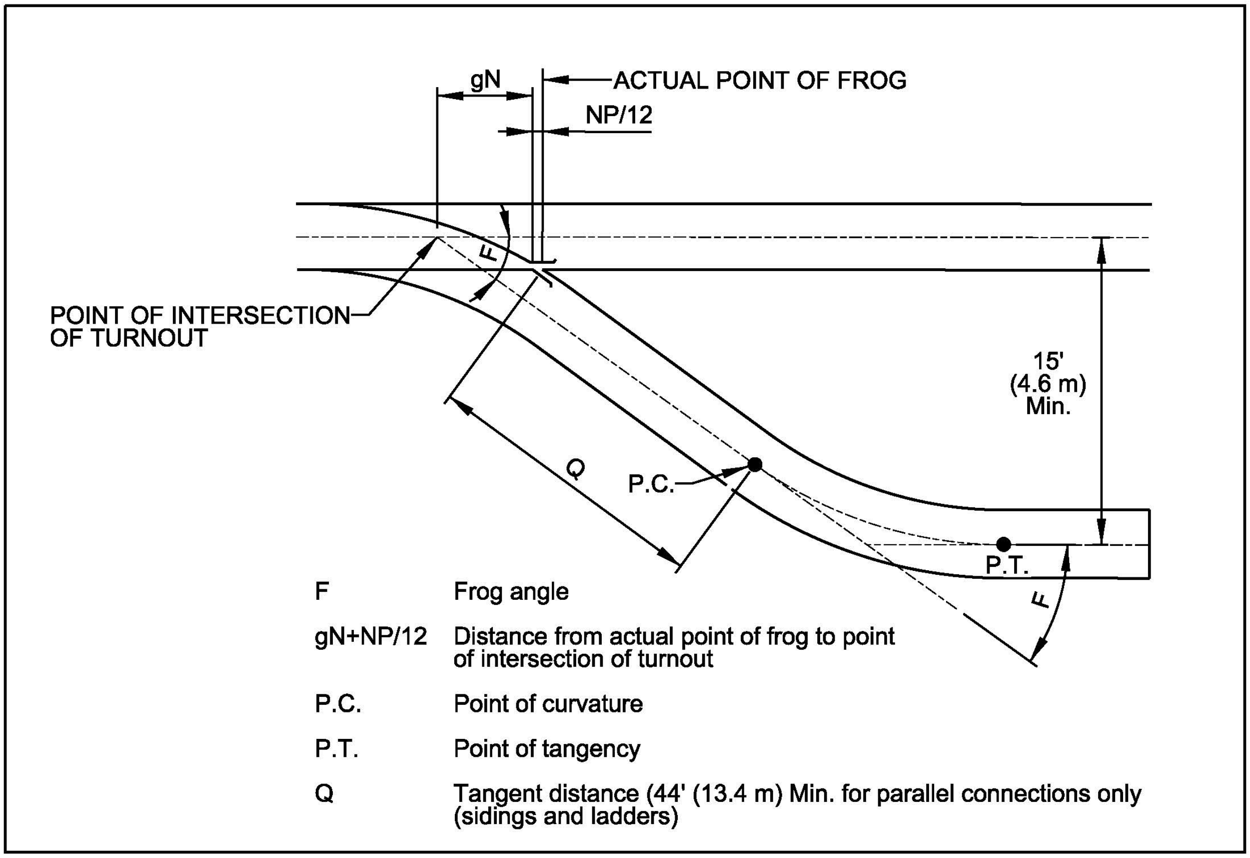


Equation 5-13. Distance from Track Center Lines to Frog Point

$$BK = g(N) + \frac{NP}{12}$$

Where:
A = Point of Switch.
AK = Actual Lead.
B= Point of Intersection of Turnout.
BK = Distance from points B to K, as shown in Figure 5-32 (feet).
C= Point of Curvature.
D = Point of Tangency.
F = Frog Angle.
g = Track gage (feet).
I = Angle between mainline and diverging route.
K = Point of Frog.
N = Frog number.
P= Frog point width = ½ in. (13 mm)
Q= Tangent distance = 60 ft. (18.2 m) minimum for diverging routes.
= 44 ft. (13.4 m) minimum for parallel connections only (sidings & ladders).

Figure 5-33 Parallel Siding Connection



5-18.3 Ladder Tracks.

Figure 5-34 illustrates a typical ladder track, shown between points A and E. This arrangement is commonly used for parallel yard tracks or loading tracks. See Chapter 7 for layout of yard and terminal tracks.

5-19 RAIL CROSSINGS.

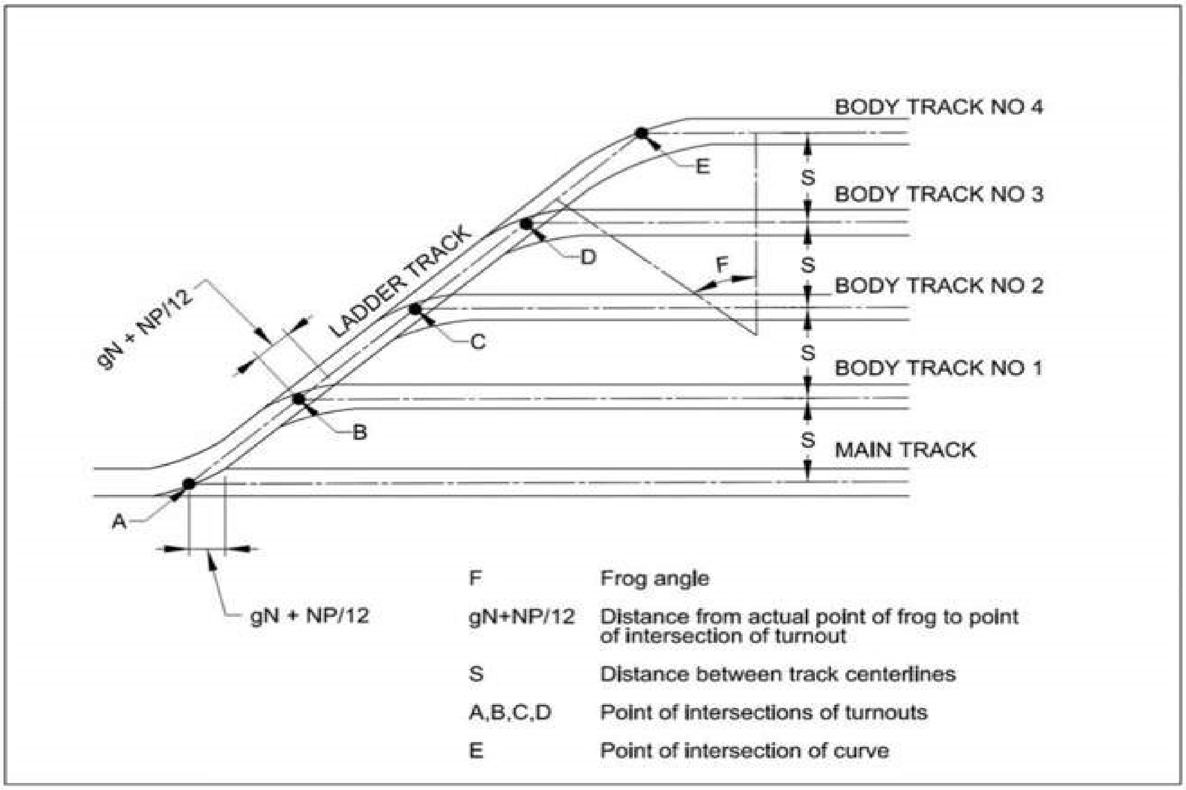
5-19.1 Recommended Types.

Bolted rail crossings, as described in item 1 on AREMA Portfolio of Trackwork Plan 700A, are recommended for use on military track. Tie layouts and plates for various angle crossings are given in AREMA Portfolio of Trackwork Plans 700F through 700J.

5-19.2 Anchoring Approaches.

Where rail anchors are used on the tracks approaching rail crossings, box anchor every third tie (four anchors per tie) for at least two rail lengths in all directions from the crossings.

Figure 5-34 Ladder Track Layout



5-19.3 Application.

As rail crossings are expensive and require more maintenance than standard track, do not design track layouts with crossing tracks unless this is clearly necessary.

5-20 MISCELLANEOUS TRACK APPLIANCES.

5-20.1 Derails.

5-20.1.1 Application and Type.

5-20.1.1.1 Switch Point Derails.

Derails are commonly used on spur tracks or sidings to prevent runaway rail cars or unauthorized entry of rail cars onto the main track. Derails are also used to protect standing equipment stored on a track. Three different types are the switch point derail, permanent hinged or sliding derail, and portable derail.

5-20.1.1.2 Permanent Hinged/Sliding Derails.

Use permanent hinged or sliding derails for permanent installations on military track. Hinged derails are typically more economical, require less maintenance, and are the most popular. Sliding derails are easier to operate if they are properly maintained. Ensure permanent hinged and sliding derails include a sign or target to indicate when they are in the derailing position and are painted AREMA yellow.

Permanent hinged, sliding, or switch point derails must include locks to secure them in both the derailing and non-derailing position.

5-20.1.1.3 Portable Derails.

Use portable derails for temporary conditions, such as protecting a construction crew that is working on a track. Paint portable derails AREMA yellow (Federal Standard 595-B, color #13538, SCN 470.0004584.1) and include an elevated blue sign with the word “DERAIL” in white lettering to indicate when it is installed.

5-20.1.2 Location.

Locate derails so that after running over the derail, a car would stop before reaching the point requiring protection. To prevent the unauthorized entry of rail cars into a main track, place derails a minimum of 50 ft. (15.2 m) beyond the point where the centerline of the track has separated 13 ft. (4 m) from the main track. Additional distance can be required depending on track gradient or the requirements of the commercial railroad. To protect standing equipment stored on a track or a work area, install the derail a minimum of 150 ft. (45.7 m) from the equipment or work area. Figure 5-35 illustrates derail placement.

5-20.1.3 Size and Designation.

Specify derails for the size of rail on which they are to be installed. The number of the derail usually indicates the distance (in inches) from the top of the rail to the top of the tie (including tie plate thickness). Derails generally come in even 1-in. (25 mm) sizes and can be shimmed up to a height of 0.5 in. (13 mm) (or the ties on which the derail is attached can be added up to 0.5 in. (13 mm) deep) to accommodate height variations.

5-20.1.4 Direction.

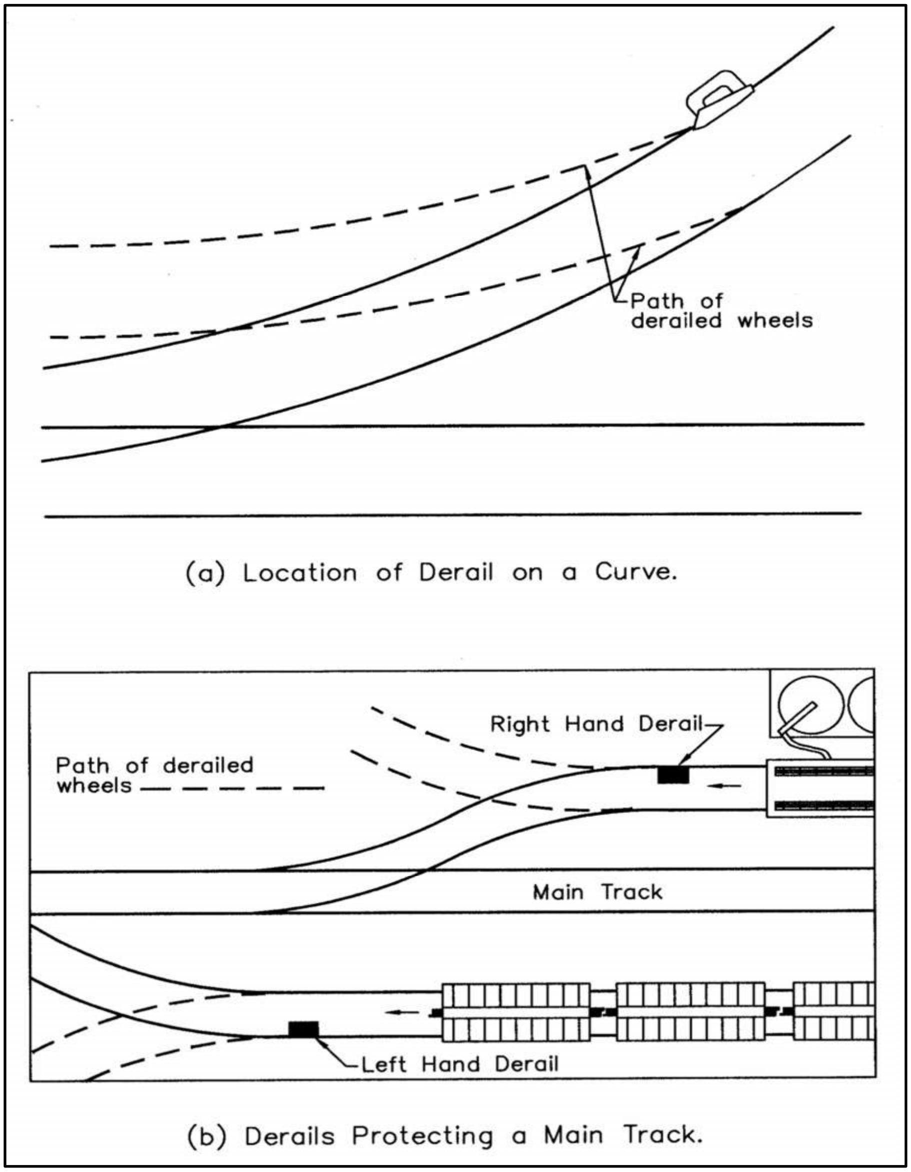
Derails are designed as either left-hand or right-hand. The proper direction is determined by looking in the direction that the rolling stock to be derailed moves. Install a right-hand derail on the right-hand rail to derail the cars off the right side of the track. Install a left-hand derail on the left-hand rail to derail cars to the left.

5-20.2 Bonded and Grounded Track.

Wherever unloading cars carrying fuel, ammunition, or other flammable or explosive materials, or where track is located adjacent to electrical equipment, bond, ground, and insulate the rails and related track materials capable of conducting electrical current from the remaining track. This bonding and grounding help prevent the discharge of static electricity during the loading or unloading of these hazardous materials. General requirements for bonding and grounding are given below; additional details are found in Chapter 33, Part 7 of the AREMA Manual.

When a side track or section of running track is to be bonded and grounded, provide an insulated joint on each rail at the first rail joint beyond the turnout of the adjacent main track at either end of the main track. The rails at all other joints in the track beyond or between the insulated joints are bonded together with bond wires and both rails of the bonded track will be connected by grounding connectors to a single driven ground rod. Remove defective bonds by shear cutting old cables immediately adjacent to the weld or pin. Do not use flames or torches to remove defective or out-of-service bonds.

Figure 5-35 Location of Derails.



5-20.2.1 Grounding Rods.

Grounding rods are 0.75-in. (19 mm) diameter copper clad steel rods or 1-in. (25 mm) diameter zinc coated steel rods. The minimum length of ground rods is 8 ft. (2.44 m).

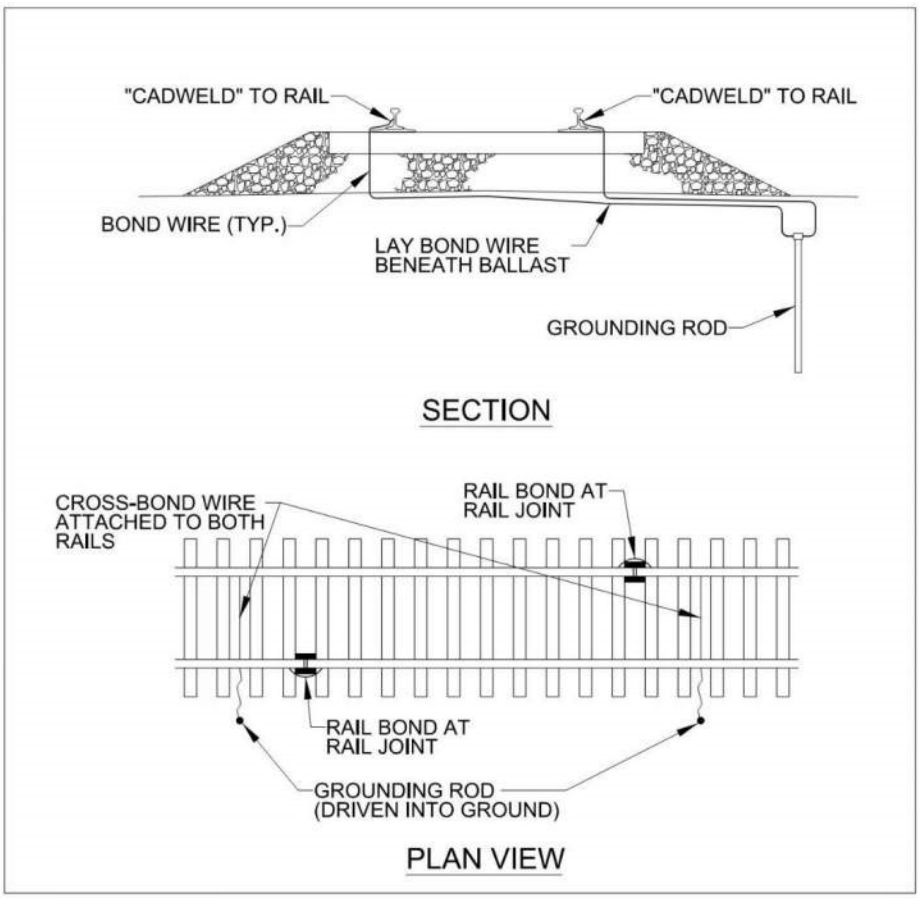
Drive ground rods vertically for their full length and ensure the top of the ground rod is located a minimum of 12 in. (304 mm) below the top of the subgrade at the toe of the ballast slope. The maximum allowable resistance of grounded rail or structures is 25 ohms. If testing indicates the resistance is greater than 25 ohms after all grounding and bonding connections are made, consult the design engineer to determine how to reduce the ground resistance below the minimum requirement.

5-20.2.2 Exothermic Rail Bond.

An exothermic type rail bond is recommended for the application of rail bonds on military track. Ensure bond cables are flexible bare copper stranded 1/0 AWG cables with preformed ends and conform to the applicable requirements.

Rail cross bonds are required to bond the two rails together and to connect the rails to the grounding rods. Install rail cross bonds using exothermic type bonds and 1/0 AWG flexible bare copper stranded cable. Apply the cross bond to the rail head or rail web and install the cable for the cross bonds a minimum of 12 in. (304 mm) below the bottom of the ties. Install cross-bonded ground rods at 100-ft (30.5 m) intervals along tracks designated for the loading and unloading of fuel, ammunition, and other volatile or hazardous materials. Figure 5-36 illustrates bonded and grounded track.

Figure 5-36 Bonded and Grounded Track



5-20.2.3 Overhead Power Lines.

Where overhead power lines in excess of 600 volts cross over the track, make the rails electrically continuous and grounded for a distance of 150 ft. (45.7 m) on each side of the power lines.

5-20.3 Track Scales.

When required, track scales will be designed and installed in accordance with the Scale Handbook, which appears as an appendix in the AREMA Manual.

The design and construction of track scales is best performed by a commercial firm that specializes in design, fabrication, and construction of railroad track scales.

5-20.4 Bumping Posts and Wheel Stops.

Use bumping posts, wheel stops, or earth mounds at the end of all stub tracks to prevent cars from rolling off the end of the track.

Where it is not critical that railroad cars be absolutely stopped at track ends to protect personnel, facilities, or parked vehicles and equipment, and where no other hazards are present, 4 ft. (1.2m) high earth mounds should be used at the end of the tracks rather than coupler-height bumping posts, wheel stops, or other obstructions. Earth mounds are economical, stop cars with minimal damage to the cars or the earth mound, are easy to repair, and are recommended by commercial railroads. An example application for earth mounds is at the ends of storage tracks. However, earth mounds must not be used with end ramps, which require the use of coupler-height bumping posts.

5-20.5 Security Fencing.

The character of the land use of property adjacent to the railroad and security requirements will govern the need for fencing along the right-of-way lines. Consult the installation Physical Security Officer to ensure that security fencing requirements are incorporated in the design. UFC 4-022-03 provides guidance on security fencing and gates. All gates are equipped with locking hardware.

5-20.5.1 Terminal Fencing.

Security fencing can be required to surround facilities within a terminal, or even a complete terminal area. These fences are typically standard chain-link construction, such as 6-ft (1.8 m) FE5 per USACE STD 872-90-02 Omaha District. When required, the following standard provides a more secure fence: FE6 USACE STD 872-90-03 or FE7 USACE STD 872-90-04 Omaha District .

5-20.5.2 Track Gates.

When designing a track gate, ensure the following:

- The gate prevents unauthorized entry by both pedestrians and vehicles.

- The gate opens a minimum width of 18-ft (5.5 m) or wider to meet the clearances in Paragraph 5-4 to allow cars to pass through.
- Culverts draining the track through a fence or gate have security bars in them.
- It is recommended that a drainage ditch security barrier be constructed using concrete. This will provide both a headwall for the culvert and a foundation to mount rollers for the sliding gate.

5-20.6 Snow Fences.

Chapter 1, Part 6 of the AREMA Manual provides guidance on the application and construction of snow fences and other measures to minimize snow drifting on the track.

5-20.7 Cattle Guards.

In areas where livestock or other large animals could enter the railroad right-of-way at road crossings, install cattle guards.

5-20.8 Utility Pipe Crossings.

Encase utility pipelines that carry liquids under pressure under or over railroad tracks within a protective steel casing pipe. Encase utility pipelines that carry gases under railroad tracks within a protective steel casing pipe or protect them using other means. Chapter 1, Part 5 of the AREMA Manual provides requirements for pressurized liquid and gas pipelines that cross railroad tracks.

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CHAPTER 6 ROAD CROSSINGS AND BRIDGES

6-1 ROAD CROSSINGS.

6-1.1 Establishing Crossing Requirements.

Verify the need for a new crossing and its appropriate location with the installation master plan. As road crossings increase maintenance costs and safety risk, limit their quantity to a minimum.

Conduct a study to assess traffic and site conditions for a newly planned crossing or one intended for upgrading or rehabilitation. These findings help establish crossing and protection design requirements. This study should include:

- Amount and character of vehicle and train traffic.
- Train and vehicle operating speeds.
- Crossing angle and horizontal and vertical approaches of road and track.
- Available sight distances, from all directions, for vehicles approaching the track and from trains approaching the crossing.
- Previous accident or incident history.

6-1.2 Design Steps.

The main steps in designing a road crossing are:

- Determining the geometric layout.
- Selecting the crossing surface and flangeway design.
- Designing the drainage.
- Designing the track section.
- Determining the appropriate crossing protection.

6-1.3 Geometric Layout.

The ideal crossing geometry is a 90-degree intersection of the track and road (for best sight angles) with slight ascending grades on the road approaches. Drainage should be away from the track to reduce the flow of surface water toward the crossing.

Avoid locating crossings near road intersections. Avoid locating crossings within either a road or railroad curve. These sites typically result in poor sight distances and in conflicting super-elevations that often lead to long-term maintenance problems and poor performance of the crossing. Where the road and railroad cannot cross at right angles, the angle should be kept to 60 degrees or greater whenever practical. For angles less than 60 degrees additional warning or crossing protection should be considered.

6-1.4 Crossing Surfaces and Flangeways.

6-1.4.1 Standard Crossing Types.

Table 6-1 lists 5 standard crossing types. Figures 6-1, -2, -3, -4, and -6 show cross sections and design details for the 5 standard crossing types. These designs are described below along with recommendations for their application and their limitations. It should be noted that, even for the most expensive crossing surfaces, the cost of rebuilding the track, especially when new rail is installed, and the road approaches is usually more than the purchase and installation cost of the crossing surface itself. Thus, especially where road traffic volume is significant, where significant numbers of heavy trucks pass over the crossing, or where vehicle speeds exceed 25 mph (40.2 km/hr), the main cost variable will probably be the expected durability of the crossing.

Table 6-1 is a starting point for matching a crossing surface with traffic requirements. The descriptions of the crossing surfaces below will help focus on the most appropriate choices.

Table 6-1 Recommended Crossing Surfaces

Crossing Type	Vehicular Traffic Use Summary
Gravel Crossing with Timber Flangeway Header.	Very low or intermittent non-public traffic volume. For use within rail yards for maintenance access.
Timber Crossing.	Low traffic volume, low truck volume.
Asphalt Crossing with Rubber Interface.	Low to medium traffic volume. For use with steel ties. Not to be used for tracked vehicle crossing.
Prefabricated Concrete Panel Crossing.	High traffic volume, high truck volume, vehicle speeds exceed 25 mph (40.2 km/hr).
Sectional Monolithic Concrete (No Ties).	Crossing designed for heavy loading. For use by tracked vehicle.

6-1.4.2 Constructed Surfaces.

Gravel and asphalt crossings are constructed crossings. With this classification, the road or street extends across the track to form a crossing. Separate flangeway headers or rubber interfaces are recommended, but the crossing is generally made from available road and track materials and fabricated on-site. This arrangement provides site-specific versatility to fit a crossing in-place at the time of construction. These crossings are readily adaptable to any track curvature, superelevation, or gradient.

These crossings are not readily removed and replaced for track or road maintenance. Construct these crossings at least 2-ft (.61 m) on each side beyond the typical pavement width for the road. Taper the crossing material at each end of the crossing forming a beveled end ramp down to the track surfacing. Note that track constructed with steel ties requires a constructed crossing surface.

6-1.4.3 Prefabricated Surfaces.

Timber, prefabricated concrete panel, and sectional monolithic concrete crossings are categorized as prefabricated. These crossings are generally ordered from a manufacturer and are assembled at the site from surface panels using special panel attachment or track fastening hardware. Prefabricated crossings often require longer ties than standard. They are ordered specifically for the size of rail, tie plates, and anchors (if used) at the crossing. This ensures the panel height will match the rail height and that sufficient clear space is available under the panels for the tie plates and rail fastenings. Also, order prefabricated crossings to match any track curvature and for crossing angles that vary significantly from 90 degrees. It is suggested that prefabricated crossings be ordered to extend at least 2-ft (.61 m) on each side beyond the widest part of the road through the crossing, allowing for crossing angle as needed. Taper the crossing at each end of the crossing forming a beveled end ramp down to the track surfacing. A fabricated metal end ramp or deflector plate fastened to the ties and crossing panel can be used in-place of a beveled crossing surface.

Prefabricated crossings are typically installed more quickly than constructed crossings and are usable as soon as installation is complete. When considering prefabricated crossings, it is suggested that drawings and instructions be obtained from a sampling of manufacturers to help determine an exact list of materials and hardware required, as well as available options and track construction and preparation requirements.

6-1.4.4 Selecting a Road Crossing Surface.

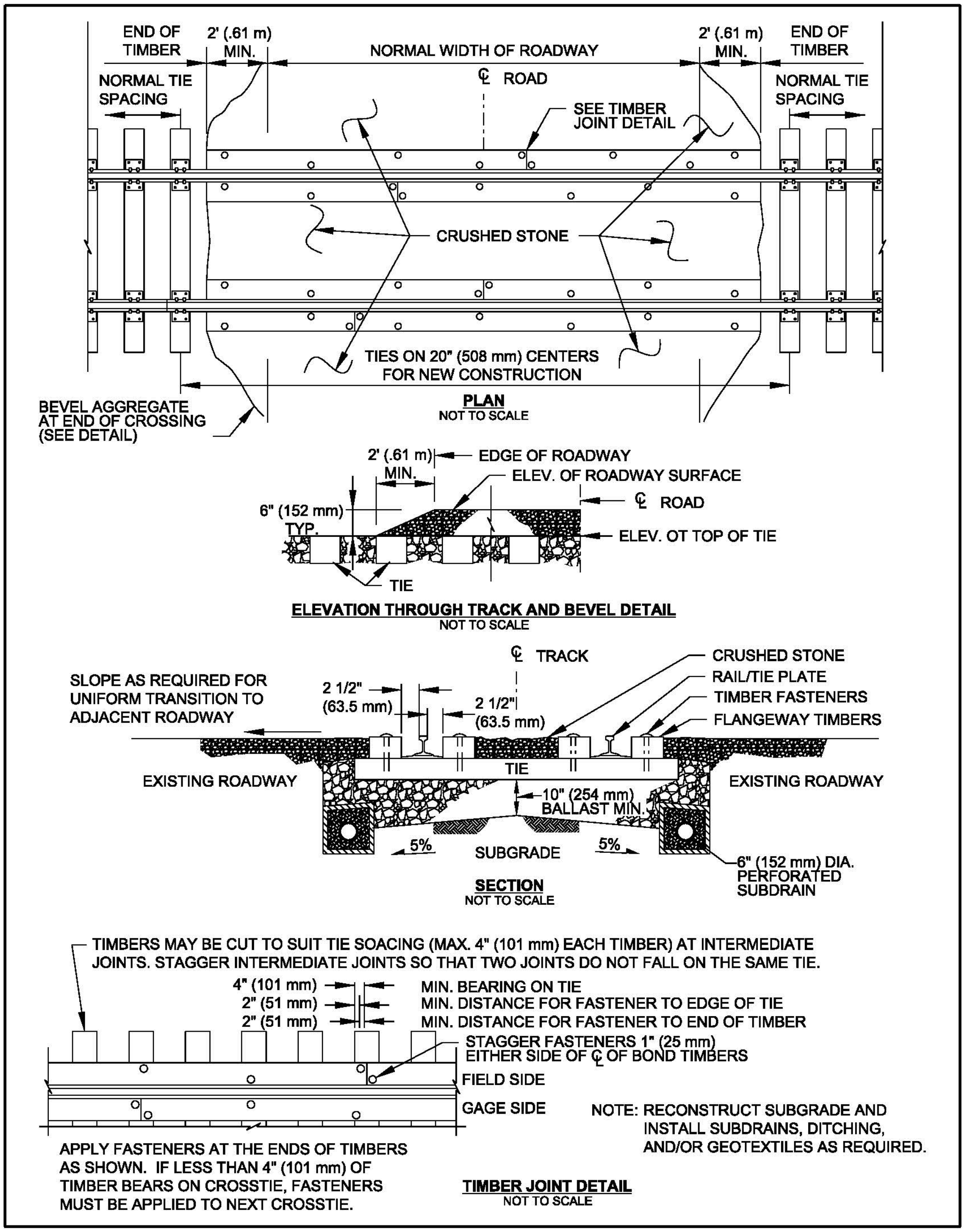
Consider the following in selecting an appropriate road crossing surface:

- Vehicle traffic – volume, type, and speed.
- Road classification – local road, collector, arterial, or highway.
- Use by industrial traffic, special vehicles, tracked vehicles.
- Railroad traffic – volume, type, and speed.
- Accident history for existing crossings where the crossing surface contributed to the accident.
- Cost – initial construction cost, replacement cost, and maintenance cost.
- Expected service life.

6-1.4.5 Gravel Crossing with Timber Flangeway Header.

These crossings are appropriate in locations with very low traffic volumes and where a crossing is infrequently used by large trucks or tracked vehicles.

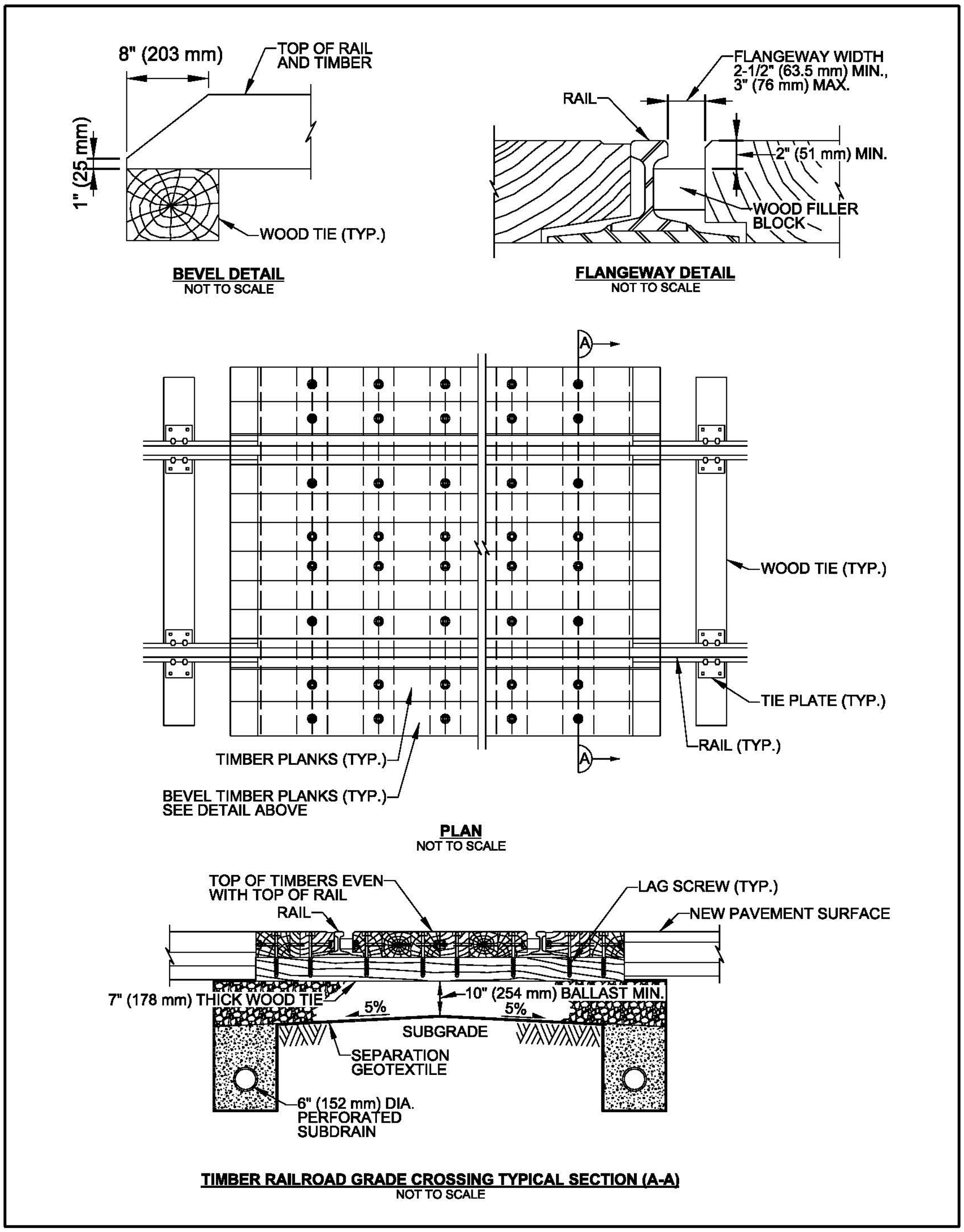
Figure 6-1 Typical Gravel Crossing with Timber Flangeway Header



6-1.4.6 Timber Crossing.

These crossings generally have a medium life span of about 10 to 15 years. They are often chosen due to long familiarity and experience with their design. If removed for track or road maintenance, however, the warping stresses that commonly build up in wood long exposed to weathering elements can make replacement difficult and produce a rougher riding surface. Timber is subject to wear that gradually exposes fastenings to vehicle tires. Timber is also subject to damage by plow blades during snow removal.

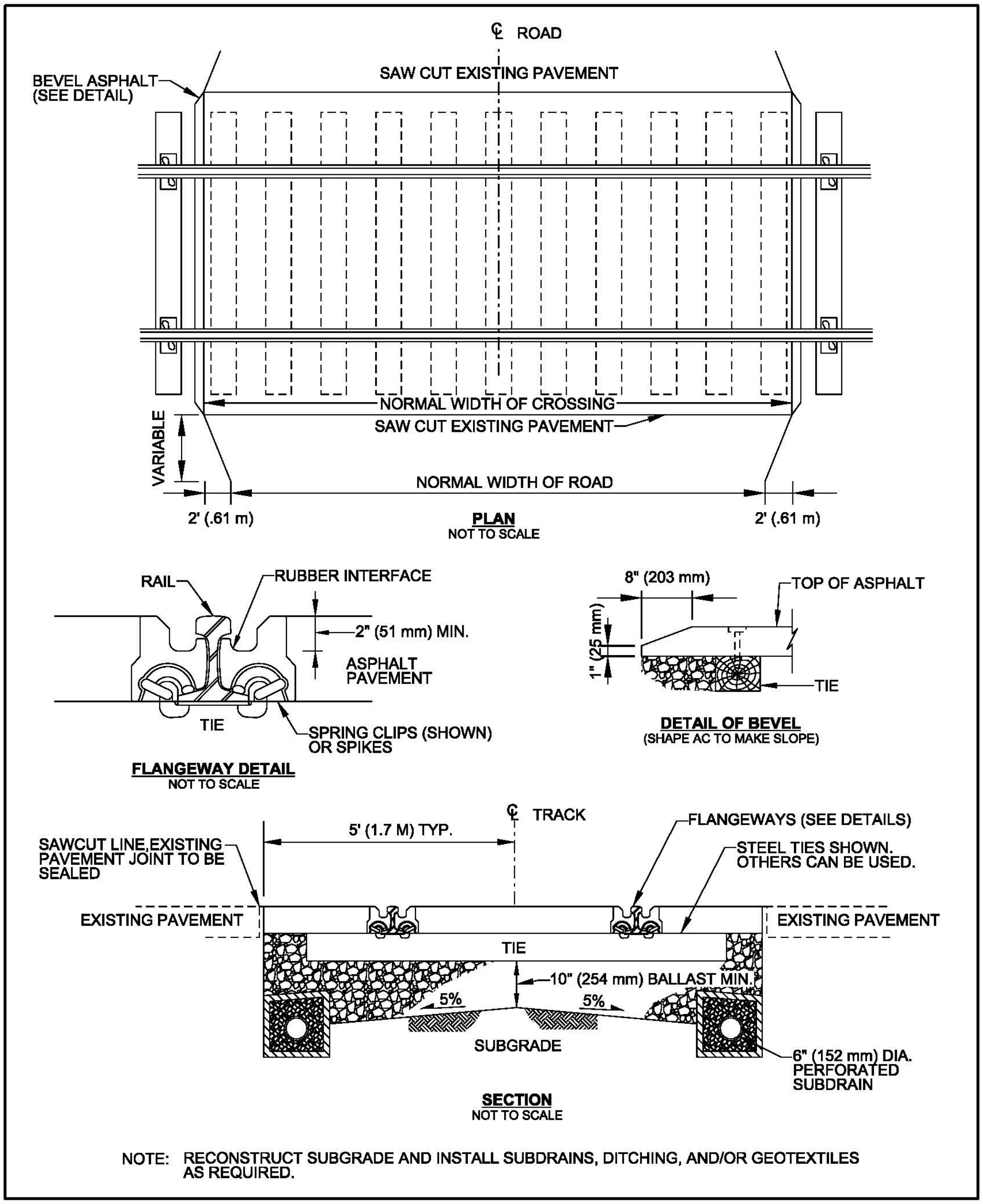
Figure 6-2 Typical Timber Crossing



6-1.4.7 Asphalt Crossing with Rubber Interface.

These are expediently and inexpensively constructed. The presence of a rubber interface providing a flangeway and separating the asphalt from the rail, typically results in reduced flangeway maintenance and less pavement breakage near the flangeway. Expected life averages 8 to 10 years under moderate traffic and where freeze-thaw cycles are common.

Figure 6-3 Typical Asphalt Crossing with Rubber Interface



6-1.4.8 Prefabricated Concrete Panel Crossing.

6-1.4.8.1 General Characteristics.

These are now being produced by a number of manufacturers and are being widely adopted due to their relative strength and expected durability, ease of installation and removal for track maintenance, and moderate cost. These crossings are not subject to decay as are standard timber crossings and are much less subject to damage from plow blades during snow removal operations, compared to timber or gravel crossings. In addition, they are the most suitable to accommodate traffic from tracked vehicles. When either track or adjacent road maintenance is required, these crossings can be removed relatively easily, in part or whole, and replaced without damage to the crossing material or track, and without loss of original evenness of surface. Like other crossings, though, these require solid support to prevent panel breakage or loss of crossing surface evenness. Due to the stiffness of the panels, these crossings are not recommended for locations where there is a pronounced vertical curve in the track.

6-1.4.8.2 Specifications.

Design of these crossings varies with manufacturer. It is suggested that a type be chosen with a minimum concrete strength of 5,000 psi (34.5 MPa), with guaranteed panel thickness variation within +/- 1/8 in. (3.2 mm), with a waterproof and chemical resistant seal on panels, and with the option of epoxy coated rebar. A warranty of crossing performance should also be obtained.

6-1.4.8.3 Installation Options.

In a standard or lagged installation, the panels are “lagged” (attached) to wood ties with lag bolts, with no fastening between adjacent panels - similar to the way a conventional timber crossing is installed. With a lagless installation, the field panels and gage panels are fastened lengthwise to form three monolithic panels for the length of the crossing, with no fastening into the ties. Different methods are used for panel-to-panel fastening. Use end angles or other end restraint devices to secure the crossing longitudinally. Vertical and lateral movement is prevented by the weight of the fastened panels combined with confinement between the adjacent roadway and the rail for field panels, and confinement between the rails for gage panels. With a lagless installation, use flangeway fillers to keep gage panels secured away from the running rails. For most military applications, lagless installation is suggested. Figure 6-5 shows a lagless concrete panel crossing in which adjacent panels are fastened by a series of short welds.

Figure 6-4 Typical Prefabricated Concrete Panel Crossing

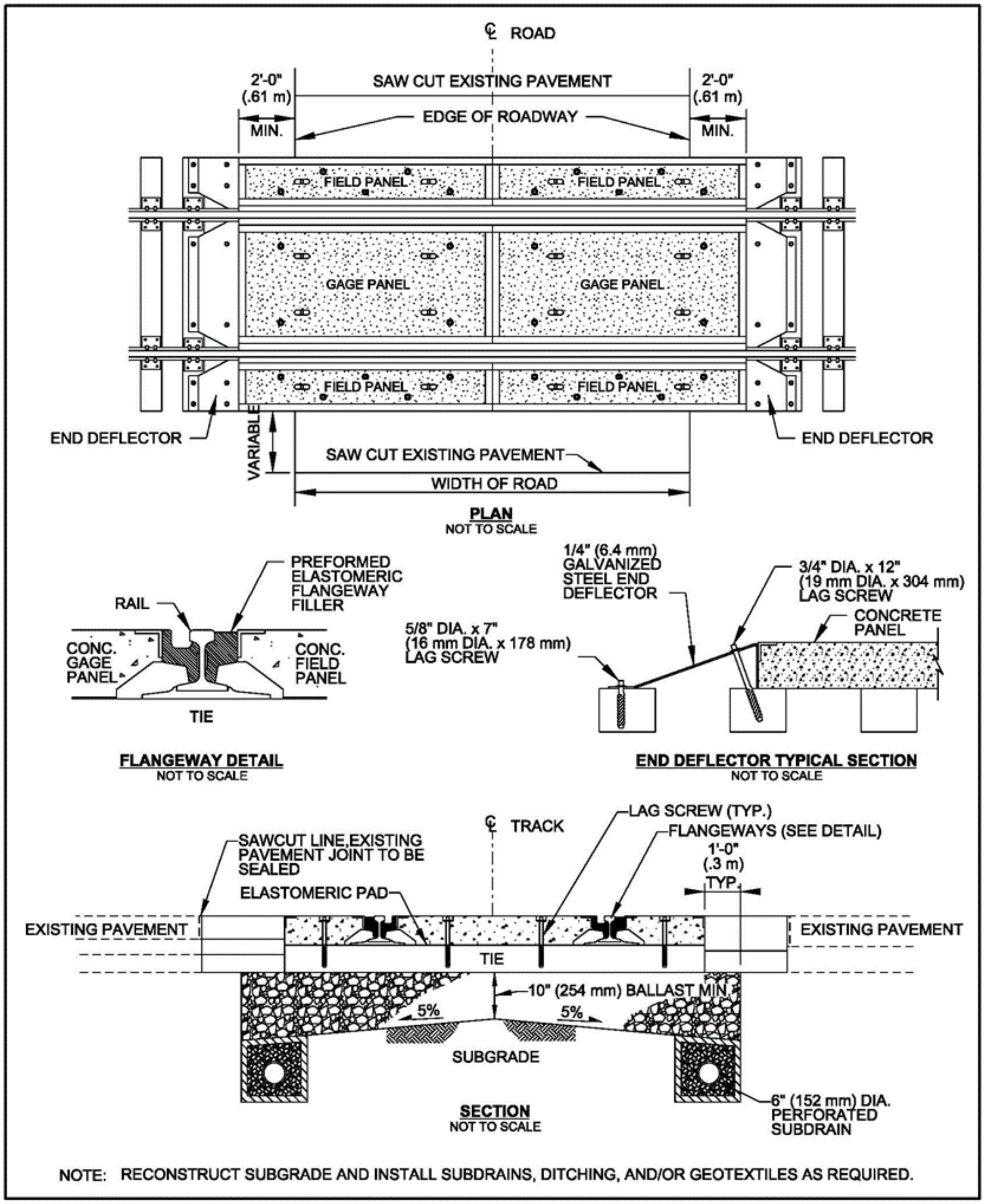
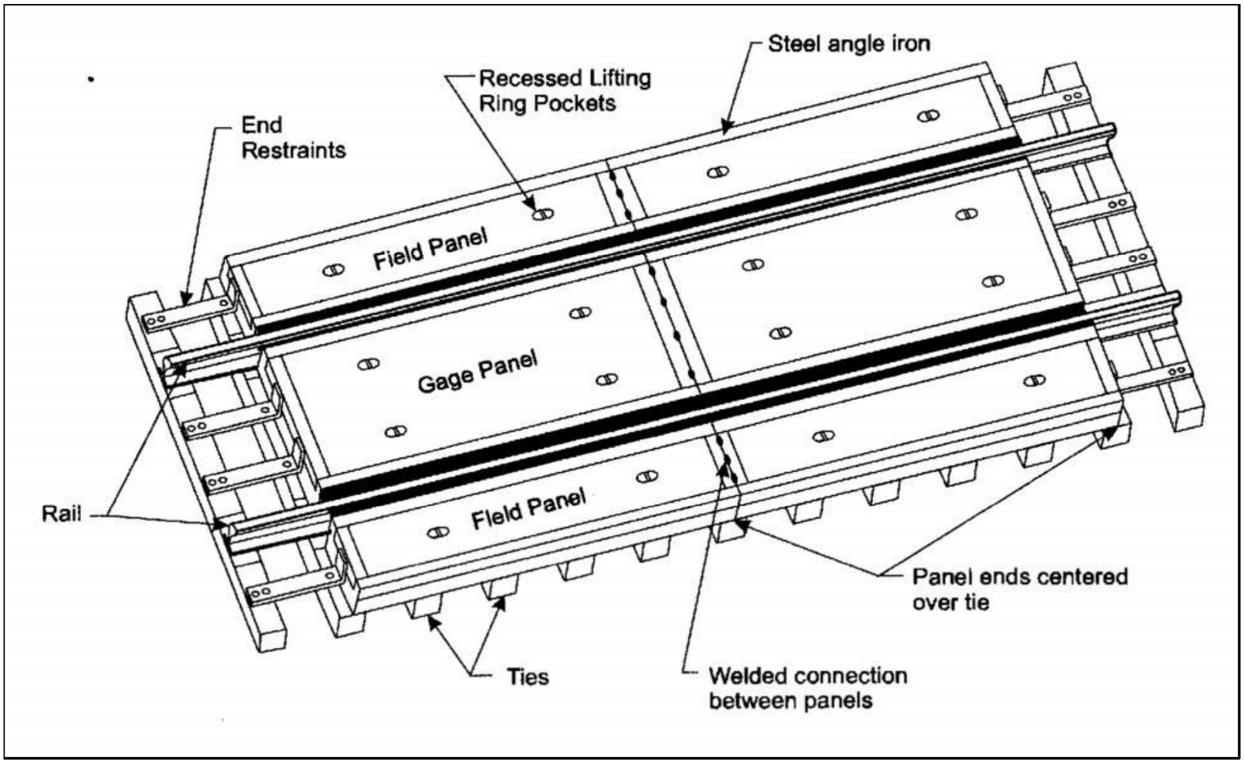


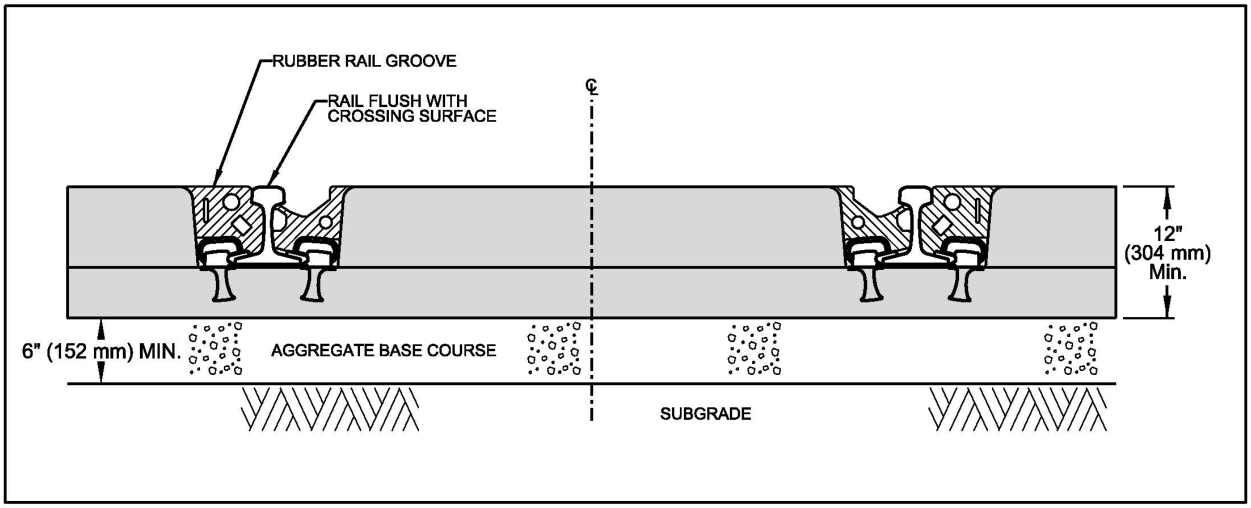
Figure 6-5 Lagless Concrete Panel Crossing



6-1.4.9 Sectional Monolithic Precast Concrete (No Ties).

These crossings essentially form a concrete roadbed and crossing surface all in one complete unit. The rails rest on rubber pads in precast concrete sections that form a solid bed. The concrete bed rests on a layer of crushed rock over a prepared subgrade. These crossings are well suited for rail service through an active container handling area or for tracks running through a concrete paved area. They are suitable for frequent heavy truck traffic and where other crossing types have not withstood the traffic and loadings. With these crossings, the rail is accessible by unbolting and removing the upper gage panels; however, since the bed is solid, the track cannot be surfaced (tamped or raised) by conventional methods. Conduct surface correction or a track raise by either completely removing the crossing sections and altering the subgrade, or for small corrections, by pressure injection of grout beneath the sections. A subgrade and base material with adequate strength and drainage are essential for good long-term performance of these crossings. These are the most expensive of the 5 crossing types – generally about twice the cost of a prefabricated concrete panel crossing.

Figure 6-6 Typical Sectional Monolithic Precast Concrete (No Ties)



6-1.4.10 Flangeways.

6-1.4.10.1 General.

These are often the most maintenance-intensive parts of a crossing. In all crossings, provide a clear flangeway space to allow unimpeded passage of the flange on railroad wheels.

6-1.4.10.2 Open or Closed Flangeways.

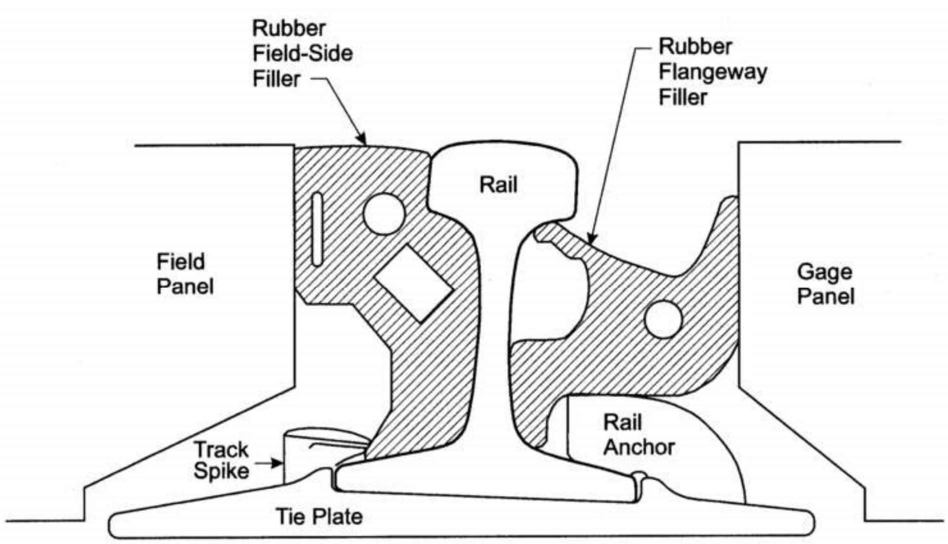
Depending on the location, opinions vary on whether the benefits of filling a flangeway exceed its costs and disadvantages. Open flangeways allow water to enter the crossing and track below, and that is highly undesirable; however, if the drainage is good, the water quickly runs off and causes little harm. Over time, dirt and debris entering an open flangeway impedes drainage. Filled flangeways are often subject to rapid build-up of dirt and debris or snow and ice. If left uncleaned, these foreign materials are typically packed in by the passage of wheel flanges and can build up to the point of blocking the flangeway and causing a derailment. Ice in a flangeway has a high probability of causing a derailment.

In summary, an open flangeway readily allows water to enter the track structure, and a filled flangeway must typically be cleaned more frequently. In areas with low annual rainfall, or where track and road gradients naturally direct water away from the crossing, an open flangeway design is preferred. In most other cases, a filled flangeway provides long term benefits by reducing the amount of water entering the track through the flangeway. A closed flangeway may also be desirable in an indoors/interior track or anywhere you would want to reduce a tripping hazard.

6-1.4.10.3 Filler Material.

The least desirable filler is asphalt. While inexpensive, it tends to crack in a short time, losing its ability to seal against water entry, and ultimately requiring time-consuming removal and replacement. Preformed or pourable rubber products are available for some crossings. Concrete panel crossings are often supplied with rubber flangeway fillers, sometimes pre-attached to the panels. Rubber fillers can have a high initial cost, but they offer a reasonably good seal against water entry, are generally long lasting, and have a flexibility that reduces the tendency of a debris-packed flangeway to cause a derailment. Rubber flangeway fillers are especially useful where: (1) crossing geometry and low relative elevation naturally direct rainwater to the crossing flangeways, (2) where crossing drainage is naturally difficult, or (3) where crossing heave from freeze-thaw cycles is a common problem from rainwater or snowmelt entering unsealed flangeways. Rubber fillers are also an alternative where asphalt filler has not held up well in the past. Figure 6-7 shows rubber flangeway fillers installed in a concrete panel crossing.

Figure 6-7 Rubber Flangeway Fillers



6-1.5 Drainage.

Ensure all prefabricated concrete crossings have a subdrainage system similar to that shown in Figures 6-8 and 6-9. Subdrainage systems are recommended for asphalt and timber crossings. Geotextile surrounding the pipe filter is optional but recommended in fine-particle soils where filter clogging is likely.

Figure 6-8 Typical Geotextile/Subdrain installation for Vehicle Road Crossings

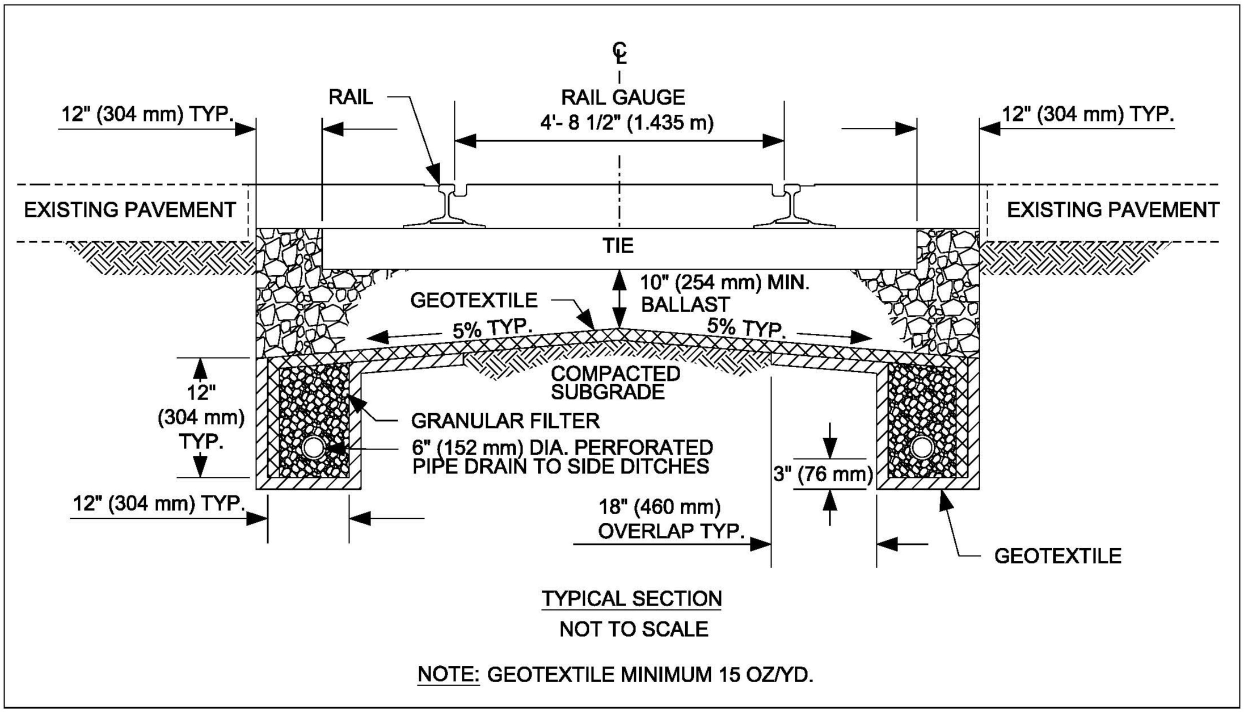
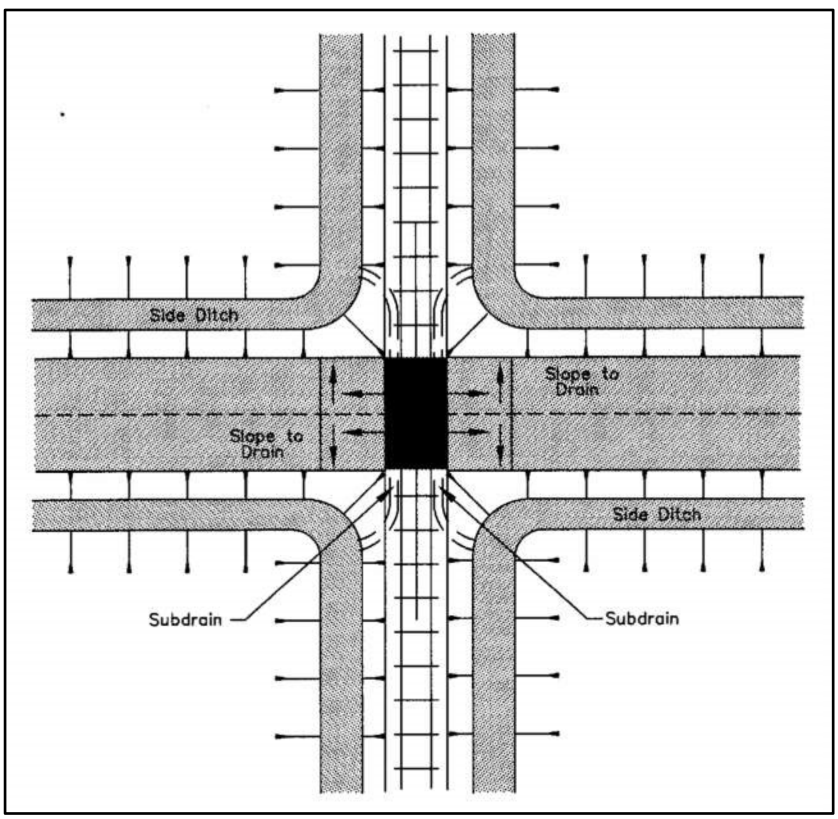


Figure 6-9 Typical Drainage at Road Crossings



6-1.6 Track Design.

Crossings do not act alone – their performance depends on adequate support from the ballast and subgrade. Unless recently constructed or repaired, rebuild the track, ballast section, and drainage system on a well-prepared subgrade before installing the crossing. Ensure the drainage system effectively transmits water outside the crossing limits.

6-1.6.1 Ties.

When crossings are built or rebuilt, replace all the ties in the crossing itself and for at least 20-ft (6 m) beyond each end of the crossing. Use 7-in x 9-in (178 mm x 229 mm) hardwood or polymer composite ties with minimum length of 9-ft. (2.75 m). Use longer tie lengths if required by the crossing manufacturer. To increase the life of the crossing, consider the use of composite ties that are 7-in x 9-in (178 mm x 229 mm) rather than wood ties. When prefabricated road crossings are installed, ensure tie length and spacing comply with the installation requirements provided by the crossing manufacturer.

If the track approaching the crossing is anchored, it is required that each tie in the crossing be box anchored and that the normal anchoring pattern be maintained throughout the remainder of the crossing area (20-ft (6 m) beyond each end).

6-1.6.2 Rail.

In crossings on main running tracks, rail of 115 lb per yd (57 kg/m) or greater is required.

As bolted rail joints in road crossings are often a maintenance problem, it is required that all joints through the crossing and for 20-ft (6 m) from either end of the crossing be welded. As an alternative, use 80-ft (24.4 m) rails to eliminate joints in the crossing area.

6-1.6.3 Geometry.

Ensure the track geometry (gage, surface and alignment) are correctly in position before covering the track with a conventional crossing surface. Failure to do so will result in a costly repair. Ensure the ballast in and around all the ties is well compacted to prevent settlement and movement of the crossing.

6-1.6.4 Flangeways.

Crossing flangeways are a minimum width of 2.5-in. (63.5 mm) with a maximum width of 3-in. (76 mm) and be at least 2-in. (51 mm) deep.

6-1.7 Road Approaches.

To reduce the amount of runoff water directed toward the crossing, road approaches are best sloped away from the crossing.

To achieve smooth riding characteristics, road approach slopes should be designed per AASHTO Policy on Geometric Design of Highways and Streets, 2018, Part 9.12.2, Figure 9-66 or subsequent latest edition. This criterion prevents low-clearance vehicles from being caught on the tracks. However, the difference in elevation between the railroad and the adjacent roadway can require steeper approaches. In these situations, verify ascending road approaches are not so steep that low-clearance truck trailers contact them. On descending road approaches, ensure gradients do not excessively lengthen stopping distances for vehicles approaching the crossing – including an allowance for wet or icy pavement. Use appropriate vertical curves to transition from the roadway grade to a level plane at the elevation of the rails. Tracks that are superelevated or a roadway approach section that is not level require a site-specific analysis.

6-1.8 Crossing Protection: Signs and Signals.

6-1.8.1 Specifications and Minimum Requirements.

Specifications for the basic design and appearance of passive crossing warning devices, such as signs and pavement markings, is given in Part 8 of the Manual of Uniform Traffic Control Devices (MUTCD). All road crossings are required to have the passive warning devices shown in the MUTCD, at a minimum. The need for additional signs or active warning devices, such as flashing lights and gates, includes consideration of the following:

- Crossing visibility or sight distance.
- Volume and speed of vehicular traffic.
- Volume and speed of railroad traffic.
- Volume of pedestrian traffic.
- Crossing geometry.
- Accident and incident history.

Further guidance on providing crossing warnings and protection can be found in the FHWA Railroad-Highway Grade Crossing Handbook.

6-1.8.2 Visibility.

Minimum clear visibility or sight distance criteria is provided for crossings without active warning devices in the AASHTO Policy on Geometric Design of Highways and Street, 2018, Part 9.12.4 or subsequent latest edition. Crossings that do not meet this clear visibility criteria require additional protection.

6-1.8.3 Traffic Character and Volume.

Consider additional protection at crossings that experience two or more train movements per day and the product of train movements and average daily vehicle traffic exceeds 3,000. This traffic threshold drops to 1,000 for crossings that are considered visually obstructed, as defined above. In addition, consider active warning devices for crossings that experience several daily train movements, have heavy truck traffic, high usage by school buses, or frequent hazardous material traffic, and where clear visibility criteria are not met.

6-1.8.4 Crossing Geometry.

Consider additional protection for crossings with a road to track angle of less than 45 degrees, or where the road approaches the track at a steep grade.

6-1.8.5 Accident and Incident History.

Consider adding flashing lights to crossings with a history of at least one serious accident, some close-call incidents, and/or where incidents of motorists not obeying existing warnings are common. If flashing lights are already present, consider adding gates.

6-1.9 Whistle Posts.

6-1.9.1 General.

Whistle posts are signs located adjacent to the track to indicate to the train crew that a road crossing is ahead. They mark the point at which the standard train horn signal for crossing approach must begin. Whistle posts commonly show just a large letter “W” on their face, but various designs are used. The installation’s operating rules can designate the sign requirements.

6-1.9.2 Location.

Whistle posts are usually located on the right side of the track (when viewed facing the crossing) at a distance that allows sufficient time to warn motorists that an engine, train, or track machine is approaching the crossing. Consult the State Department of Transportation and the installation for requirements on whistle post location. The appropriate location will depend on factors that include the speed of railroad traffic, speed of vehicle traffic, and the visibility at the crossing. A commonly used guideline is that the crossing warning signal must begin sounding at least 20 seconds before an engine, car, or track machine reaches the nearest end of the crossing.

6-2 BRIDGES.

6-2.1 Deck Types.

Classify railroad bridges by deck type: open deck or ballast deck. In a typical open deck bridge, every second or fourth tie is bolted directly to the structure; thus in effect, the track becomes part of the bridge. In a ballast deck bridge, a standard track and ballast section are supported on a solid floor. The ballast deck has the advantage of allowing the track across the bridge to be lined and surfaced in the same fashion as standard track.

6-2.2 Design Procedures.

When a bridge is required, the bridge structure is designed by a practicing railroad bridge engineer in accordance with the AREMA Manual: Chapter 7 for timber structures, Chapter 8 for concrete structures, or Chapter 15 for steel structures. Part 9 of AREMA Chapter 15 provides background and commentary on railroad bridge design practices.

6-2.3 Basis for Design.

The design of railroad bridges is based on two main factors: the magnitude of loads applied to the bridge and the expected level of traffic (or number of stress cycles) over the design life of the bridge. One stress (or load) cycle is defined by one application and release of loading on a bridge member.

6-2.4 Live Load.

Use Cooper E-80 live load as shown in Figure 6-10 for the design of railroad bridges. If the bridge will be a steel structure, consider the Alternate Live Load shown in Figure 6-11. Use the live load that produces the greater stress for the design. Consider both Cooper E-80 and the Alternative Live Load for the design of each element in a steel structure. Use only Cooper E-80 live load for the design of timber and concrete bridges.

Figure 6-10 Cooper E-80 Live Load Configuration for Bridges

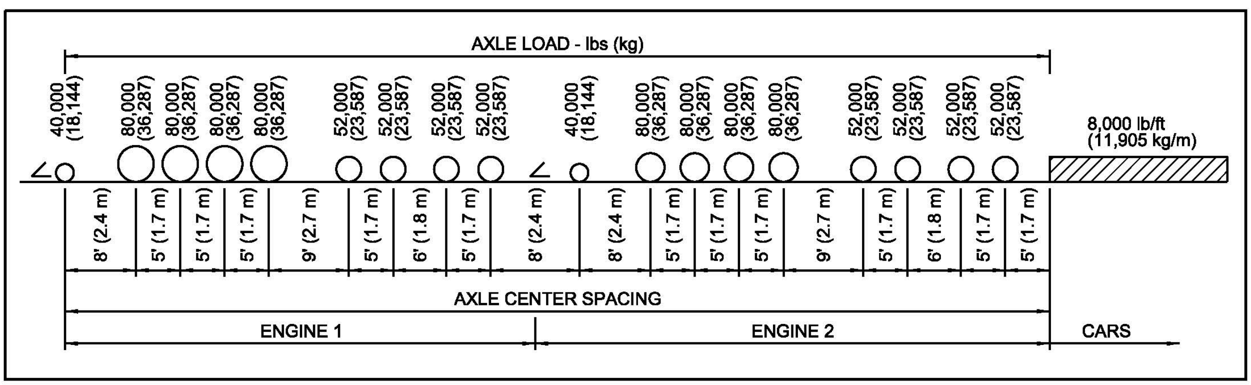
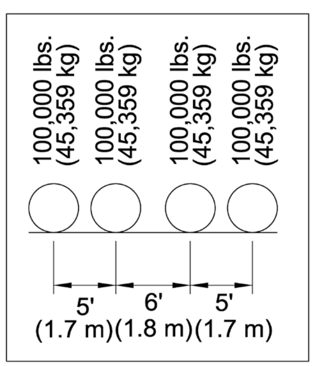


Figure 6-11 Alternative Live Load for Steel Structures



6-2.5 Walkways.

When bridges are located in areas where switching movements are made and at other locations where it is either useful or necessary for people to walk alongside a train (or cut of cars), provide walkways on at least one side of a bridge. Where people require access to both sides of the track when a bridge is occupied, provide walkways on both sides. Workers are never allowed or expected to cross the track by going under cars, crossing over couplers, or climbing over cars.

6-2.6 Tie Pads.

On open deck bridges, installation of rubber tie pads between the tie and tie plate is recommended.

6-2.7 Bridges Spanning over Railroads.

Design bridges spanning over railroads to have adequate horizontal and vertical clearance from the railroad tracks. Locate piers so they provide more than 25 ft. (7.6 m) of horizontal clearance from the centerline of existing tracks and possible future tracks. If less than 25 ft. (7.6 m) of horizontal clearance is provided, install crash wall pier protection.

Design crash wall pier protection per AREMA Chapter 8, Article 2.1.5.1. Crash walls for piers 12 to 25 ft. (3.6 to 7.6 m) clear from the centerline of track require a minimum height of 6 ft. above the top of rail. Crash walls for piers less than 12 ft. (3.6 m) clear of the centerline of track require a minimum height of 12 ft. (3.6 m) above the top of rail. If crash walls are used, the minimum required horizontal clearance for piers is as specified in Chapter 5, Paragraph 4. The minimum vertical clearance for bridges spanning over railroads is also specified in Chapter 5, Paragraph 4. Survey the profile of existing tracks for 1000 ft. (304.8 m) each side of a proposed overhead bridge. If the profile indicates a sag at the proposed bridge location, increase the vertical clearance sufficiently to permit raising of the track to remove the sag.

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CHAPTER 7 TERMINALS

7-1 INTRODUCTION.

This chapter addresses the design of railroad terminal and support facilities that are primarily intended to support unit mobilization. Obtain design and planning information for terminals at supply depots or ammunition plants from the Construction Branch of the Army Material Command.

Terminals contain track and facilities for:

- Loading and unloading: tracked and wheeled vehicles, containers, equipment, ammunition, fuel, and general supplies.
- Holding: empty cars waiting to be loaded or loaded cars waiting to be unloaded, or cars that require repair or adjustment of the load or tiedowns.
- Switching: maneuvering cars around the terminal, re-ordering or turning a line of cars, or allowing an engine to get on either side of a cut of cars.
- Interchange: holding loaded or empty cars waiting to be picked up by the connecting commercial railroad, or cars delivered to the installation by the commercial railroad.
- Storage: for cars infrequently used or moved.
- Fueling and housing engines.

7-2 SITING AND GENERAL LAYOUT.

In the siting and layout of terminals, consider space requirements, logistics, security, safety, the presence and use of existing facilities, character of the terrain and natural drainage, as well as mission requirements. When locating a terminal area, select a site that has the correct size, shape, and orientation so that it provides convenient access for both vehicles and railroad service.

Where space is limited, consider two or more separate terminals to provide sufficient capacity. This option can generate better traffic flow and less congestion than at a single site but can complicate command and control of loading operations and security arrangements.

7-3 TRACK DESIGN.

7-3.1 Design Wheel Loads.

For through running tracks in terminal areas, use Table 2-2, “10 MPH (16 km/hr) or Less.” For tracks where cars are simply placed and removed (as distinguished from those where general running or back and forth switching movements frequently occur) such as warehouse sidings and spur tracks (dead end tracks), including loading and storage tracks, use Table 2-2, “Light Use.” For run-around tracks, passing sidings, yard tracks, wyes, balloon tracks, or other tracks where switching movements commonly occur, use Table 2-2, “10 MPH (16 km/hr) or Less.”

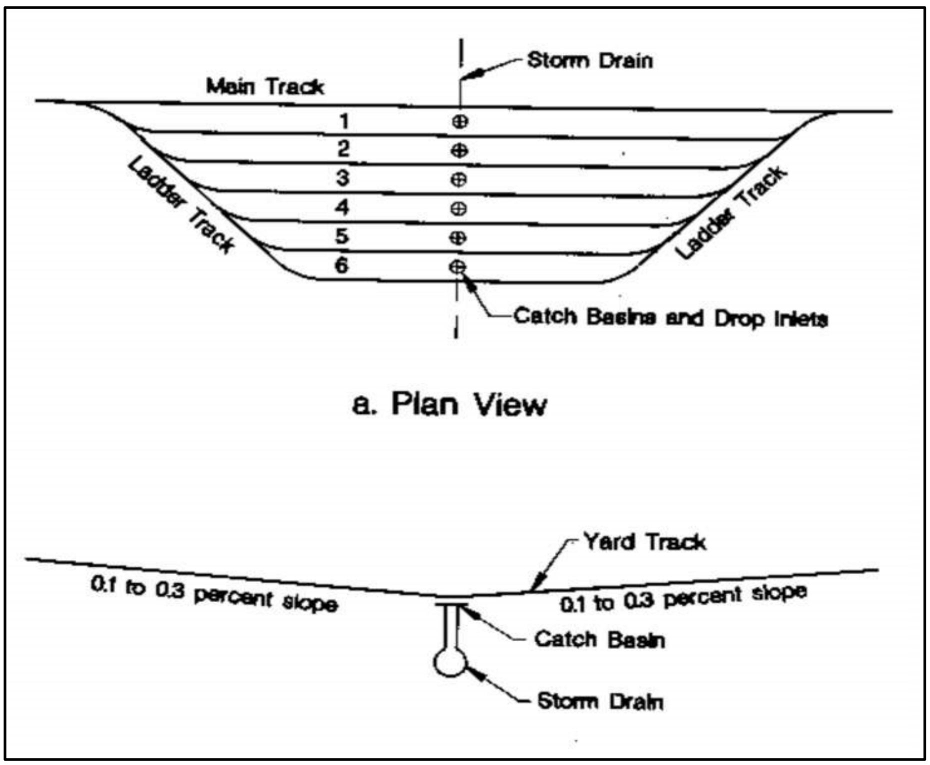
7-3.2 Gradients.

Do not allow gradients on running tracks through a terminal to exceed 1.0 percent. On auxiliary tracks where cars are temporarily left standing during switching, gradients cannot exceed 0.3 percent. Gradients on tracks where cars will be left standing for 1 or more days, such as loading, yard, and storage tracks, preferably do not exceed 0.2 percent, with a maximum allowable of 0.3 percent. It is desirable to have these tracks slope away from the main track or connecting track. Thus, if hand brakes do not properly hold on cars, they would not roll toward the main track.

7-3.2.1 Double-End Yards.

Double-end yards are best graded as shown Figure 7-1, with tracks sloping toward the center, where storm drainage is provided. This grading arrangement prevents cars from accidentally rolling toward either ladder track and will also facilitate drainage by collecting runoff at the center of the yard.

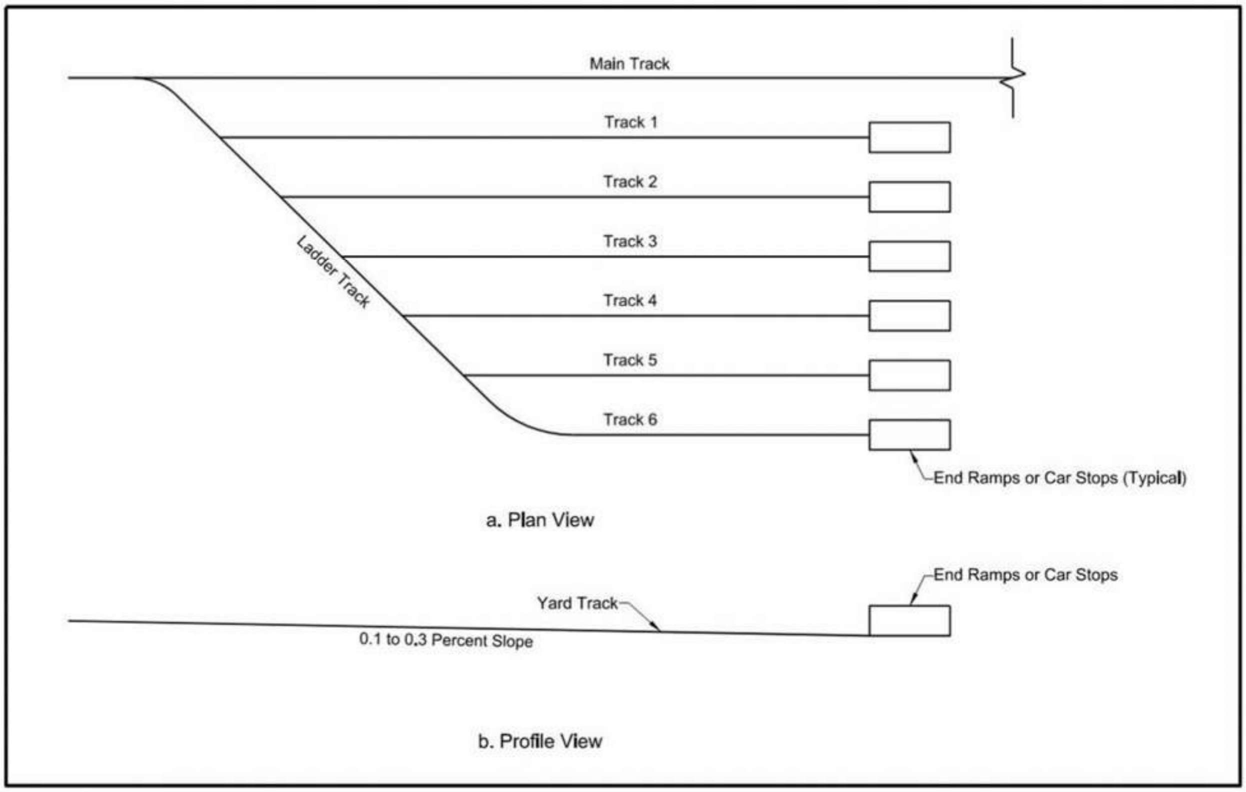
Figure 7-1 Typical Double-End Small Yard with Storm Drainage



7-3.2.2 Single-End Yards.

Grade single-end (also known as dead-end) yards as shown in Figure 7-2, with tracks sloping toward the end ramps or car stops.

Figure 7-2 Typical Single-End (Dead End) Small Yard



7-3.3 Vertical Curves.

Design guidance for vertical curves in terminals is provided in Table 5-1.

Do not locate turnouts in vertical curves. Turnouts in vertical curves result in problems with point fit and operation.

7-3.4 Horizontal Curves.

Design guidance for horizontal curves in terminals is provided in Table 3-3.

7-3.5 Track Layout.

Design guidance for the layout of turnouts, curves, ladder tracks, and track connections is covered in Chapter 5.

7-4 CLEARANCES AND USABLE TRACK LENGTH.

As terminal track is typically closely spaced near loading docks, buildings, access roads, parking and staging areas, parallel tracks, etc., awareness of clearance requirements is especially important. Clearance requirements are covered in Paragraph 5-4.

The maximum usable track length for positioning cars extends from the end of track (for spur tracks) to the clearance point, or (for sidings) between two clearance points, as indicated in Figure 5-9.

7-5 VEHICLE TERMINALS.

7-5.1 Purpose and Facility Requirements.

A vehicle loading terminal is generally designed for transferring tracked or wheeled vehicles on or off flatcars or, in the case of smaller wheeled vehicles, bi-level auto racks. A vehicle terminal will contain the following:

- Loading tracks to position the flatcars.
- Staging area to hold the vehicles.
- End ramps or multilevel ramps for transferring the vehicles to and from the railroad cars.
- Railyard operations building.
- Storage building for tie-down, blocking, and bracing material.
- Lighting for terminals and staging areas with operations after dark.

7-5.2 Track Spacing.

When the loading tracks in a vehicle terminal are laid out parallel to each other (as is often the case), the tracks are typically paired as shown in Figure 7-3. The minimum track spacing between tracks in a pair is 22.5-ft. (6.9 m). The minimum track spacing between track pairs is 50-ft. (15.2 m). 22.5-ft. (6.9 m) is the minimum track spacing for small utility terrain service vehicles to drive between the tracks. Bridge plate storage racks can be located in the 50-ft. (15.2 m) space between track pairs.

7-5.3 Track Length and Number of Tracks.

For vehicle loading, strings of between 10 and 20 cars are most effectively handled at a time: the lower limit of 10 to minimize switching requirements and the upper limit of 20 to limit the length needed to drive vehicles down the string of rail cars for efficient loading. As a result, each loading track has a tangent length extending from 10 to 20 car lengths from the loading ramp, as shown in Figure 7-4. For multi-level ramps, only handle a maximum string of 6 rail cars at a time.

The number of tracks required can be determined from the traffic and mission information covered in Chapter 2, the space available in the terminal area, and the criteria for track length above.

Figure 7-3 Vehicle Terminal

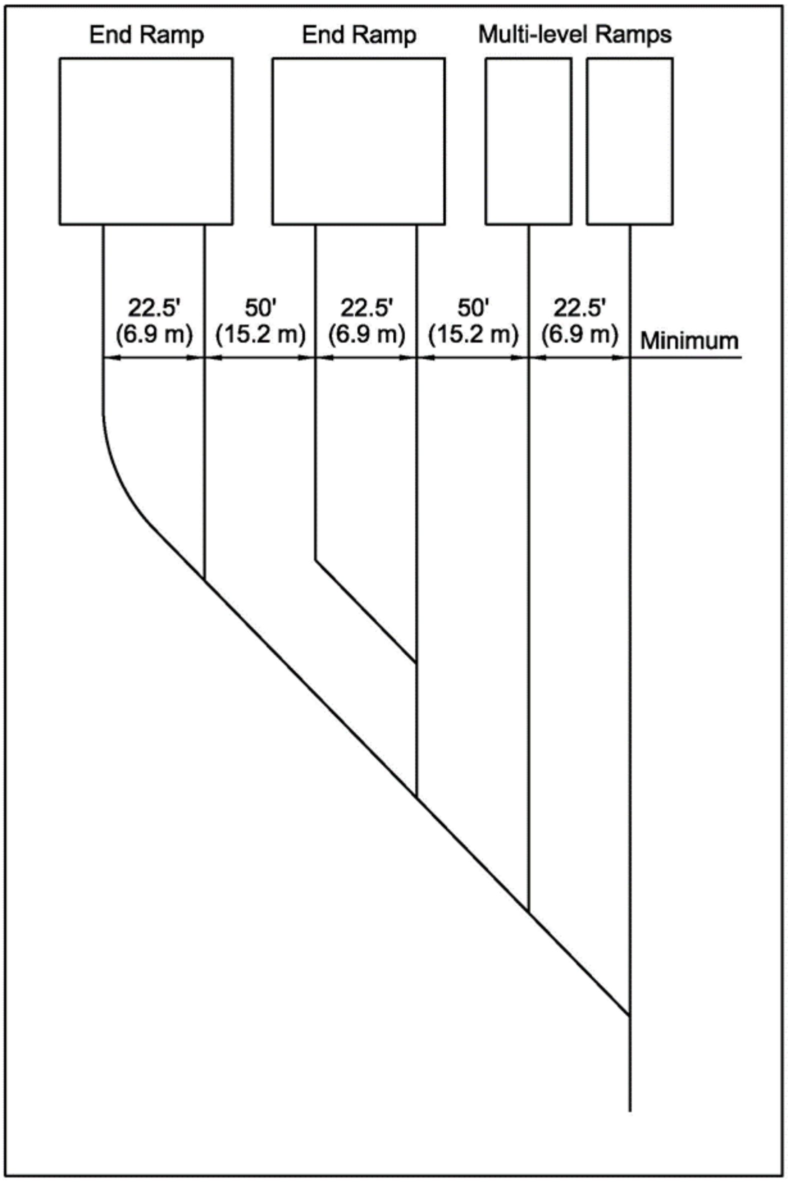
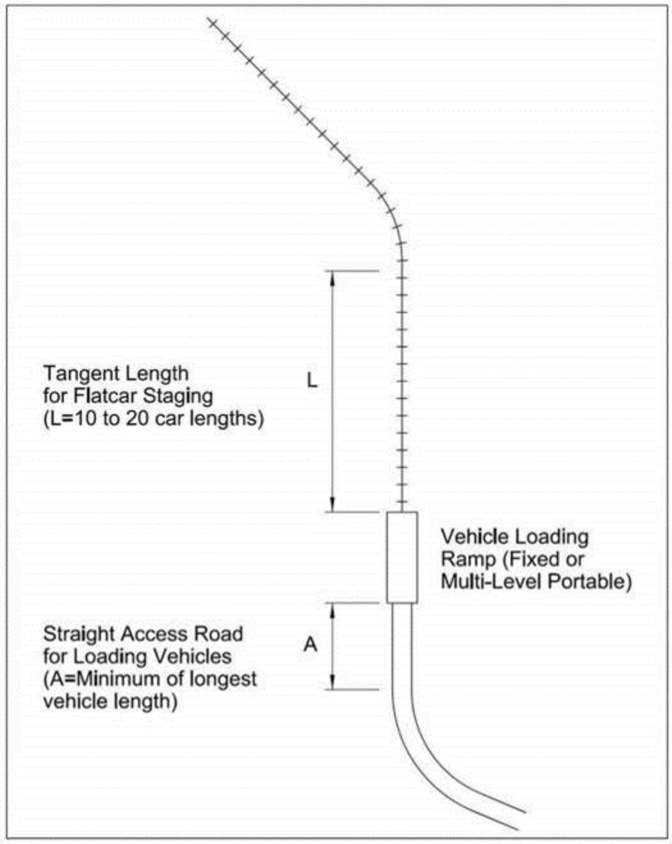


Figure 7-4 Track and Approach Road Lengths for Vehicle Loading



7-5.4 Staging Area.

The size and location of a vehicle staging area depends on terrain characteristics and availability of space. Locate the staging area as close to the loading area as possible to facilitate better command and control. Ensure the staging area is large enough to stage one full loading cycle of vehicular cargo, thus a loading terminal with a capacity of 50 flatcars would require a staging area with a capacity of 50 carloads of vehicles.

The staging area requires an access road or approach leading up to the loading ramp, which is straight and in line with the ramp for at least the full length of the longest vehicle to be loaded. If practical, the in-line approach is twice the length of the longest vehicle to ensure that a vehicle can always be positioned ready to load as the first vehicle is driven up the ramp. It is also preferable that this road is not directly adjacent to any track to avoid a dust cloud from the approaching vehicles reducing the view of loading operations.

For operation after dark, staging areas need to be lighted with “parking lot” type lighting. Fencing is required if the cargo is security sensitive. (See Chapter 5, Paragraph 20.5).

7-5.5 End Ramps for Tracked and Larger Wheeled Vehicles.

Rapid loading of larger vehicles onto flatcars is best accomplished with permanent end ramps constructed at the end of the loading tracks. While end ramps can be constructed with concrete, wood, steel or retained earth, they must support the largest and heaviest vehicles mobilized: typically a main battle tank. A general reinforced concrete ramp design is shown in Figure 7-5. Obtain more detailed guidance from the Army Transportation Systems Center (CENWO-ED-TX, or at website: https://transportation.erdc.dren.mil/tsmcx/). A well-designed end ramp will:

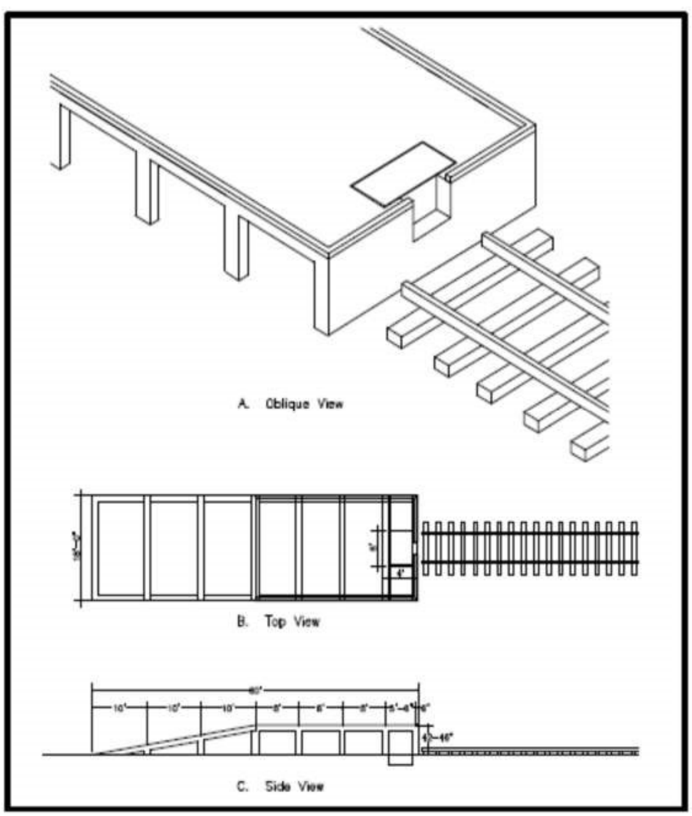
a. Allow an M-1 Abrams tank to be driven onto a flatcar having the lowest platform height used in commercial railroad service. Note: It is safer and easier to drive a vehicle from a lower ramp level to a higher flatcar level than vice-versa.

b. Provide ample width to enable guides to walk on both sides of an M-1 tank.

c. Provide sufficient level platform length to allow a tank to be in a completely horizontal position prior to proceeding onto the railcar.

d. Have the proper transition between the incline and the level platform so that a tank will not "high center" itself while negotiating the ramp.

Figure 7-5 Concrete End Ramp



To make vehicle loading easy, it is desirable to have the end of the rail car close to the ramp platform. It is also necessary to protect both the rail car and the ramp from impact damage when rail cars are being positioned at the ramp. As rail car designs vary (draft gear length, amount of end overhang, position of uncoupling lever, etc.), this protection cannot be reliably provided by fastening wheel stops to the track. The design in Figure 7-5 incorporates a cut-out at the front of the ramp at the height of the car coupler. Behind the cut-out is a concrete block separated from the remaining ramp structure with cushioning (expansion joint) material. This concrete bumper block reduces the likelihood of impact damage to the ramp. Other shock absorbing designs and devices can be used as well, including commercial railcar buffers. Select the method best suited for the particular application. While the concrete bumper block could easily be incorporated into new construction, it might prove impractical during rehabilitation if the existing ramp platform will not be extensively modified.

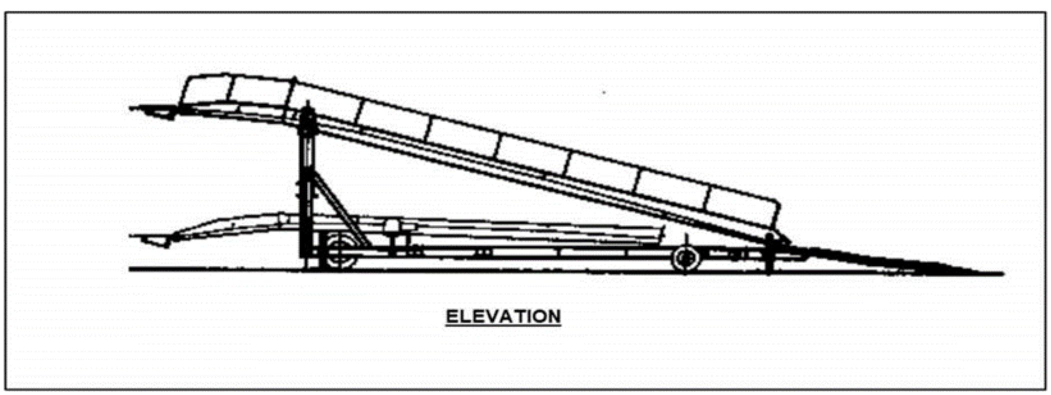
7-5.5.1 Spanners.

To permit wheeled vehicles to cross the gap between the ramp and the flatcar, spanner boards are necessary; tracked vehicles do not require spanner boards. Thus, if fixed spanners are used, ensure they are detachable so that they will not interfere with the loading and unloading of tracked vehicles.

7-5.6 Multilevel Ramps for Smaller Wheeled Vehicles.

If an installation has a requirement to mobilize large quantities of small-wheeled vehicles, it is recommended that multilevel ramps be used to load bi-level railcars. These ramps are portable pieces of equipment that can either be purchased and maintained by the installation or leased from a commercial railroad when needed. Like end ramps, multilevel ramps are positioned at the end of a track spur. A typical multilevel ramp is shown in Figure 7-6.

Figure 7-6 Portable Multilevel Ramp05



It is important that the ground underneath a multilevel ramp be level and capable of bearing the weight of the ramp plus the heaviest vehicle being loaded. A Portland cement concrete pad is recommended to ensure good ramp stability.

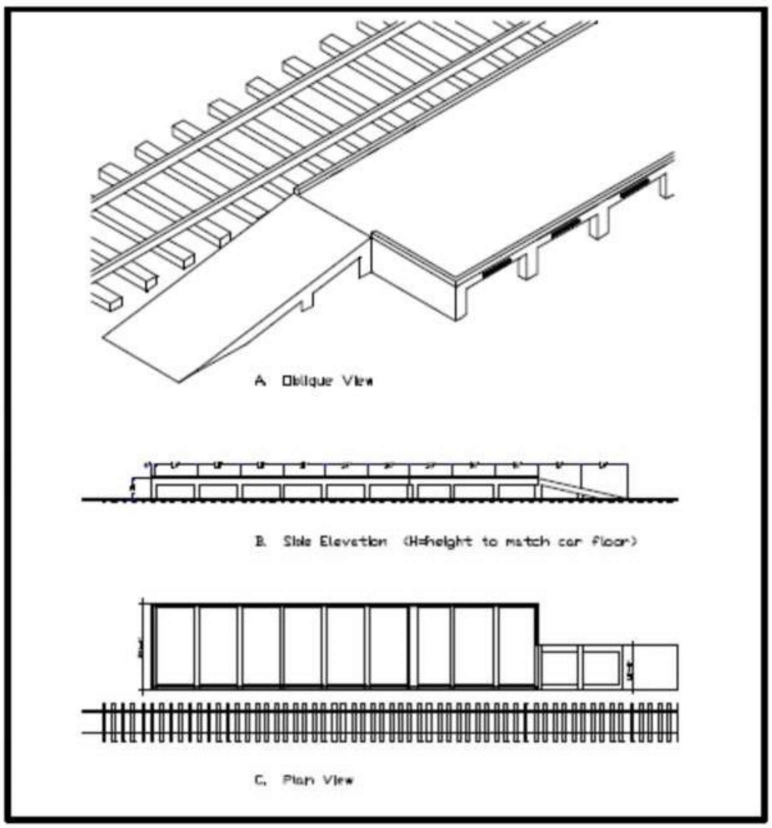
7-6 BREAK BULK (SMALL CARGO) TERMINALS.

Permanent side ramps, parallel to the track, are recommended for loading break bulk cargo into boxcars. For staging cargo, large open areas are needed surrounding the ramps. Thus, where several parallel tracks run through a terminal, construct the ramps along the outermost tracks. Figure 7-7 shows a diagram of a reinforced concrete side-loading ramp.

Side ramps are required to meet the following design criteria:

- Capable of supporting the weight of a fully loaded 4,000-lb (1815 kg) forklift.
- Allow sufficient area for a forklift to maneuver.
- A height convenient for a forklift to drive into a boxcar on the adjacent track as well as into a truck docked at the ramp.
- Incline angle small enough for a forklift to easily negotiate it.

Figure 7-7 Side Loading Ramp



7-7 CONTAINER TERMINALS.

A container loading area includes at least one track spur with sufficient space on one or both sides of the track for a container handler to operate. The required size of a container terminal is related primarily to the largest volume of cargo required to be handled in the shortest time period. General plans and additional design guidance for container terminals can be found in Chapter 14, Part 4 of the AREMA manual.

Use the following design criteria for a container terminal:

- Include at least one straight spur track long enough to hold a minimum of five flatcars.
- Have one entrance and one exit to the yard area located to establish a one-way circular traffic flow.
- Have sufficient open area for a Rough Terrain Container Handler (RTCH) to efficiently operate.
- Have a surface that will support the weight of a RTCH carrying a loaded 40-ft container.
- For night operations, have “Parking Lot” type lighting positioned so that the light poles will not interfere with the operation of the RTCH or truck-trailers operating inside the yard.
- If a secured area is required, have a perimeter fence with a gate across each track entry and exit (see Chapter 5, Paragraph 20.5).

7-8 AMMUNITION TERMINALS.

Design ammunition terminals to meet the required shipping volume at the installation. Set up the terminal as either a break bulk terminal (Chapter 7, Paragraph 6) or a container terminal (Chapter 7, Paragraph 7). In addition to the usual terminal requirements, incorporate the following Explosives Safety standards into the design:

- Refer to service specific Explosives Safety guidance to determine the minimum Explosive Safety Quantity Distances (ESQD).
- Generally, yards will be laid out on a unit car-group basis with each car-group separated by the applicable above-ground magazine distance.
- If the yard is formed by two parallel ladder tracks connected by diagonal spurs, the parallel tracks and the diagonal spurs will be separated by the applicable above-ground magazine distance for the unit group quantities of high explosive.
- If the yard is a tree arrangement, consisting of a center ladder track with diagonal dead-end spurs projecting from each side at alternate intervals, separate the spurs by the applicable above-ground distance for the net quantity of high explosives in the cars on the spurs.
- Separate railroad yards from other facilities by the applicable Quantity-Distance standards.

The following recommendations also apply to ammunition loading areas:

- If loaded ammunition cars will stay in a terminal area for sufficient time, fence the areas completely, with gates across all tracks entering the area, and have locking pedestrian and vehicular gates. See Chapter 5, Paragraph 20.5.
- Lighted with "parking lot" type lighting.
- If guard towers are required, position them to allow observation of the entire ammunition loading area.

7-9 PETROLEUM, OIL AND LUBRICANT (POL) TERMINALS.

The design of POL handling and storage areas is regulated by Federal, State, and local environmental protection agencies as well as State and local fire marshals. Contact these agencies when designing POL facilities and incorporate appropriate design standards.

POL handling and storage areas are required to be completely fenced, with gates across all tracks entering the area and have locking pedestrian and vehicular gates (see Chapter 5, Paragraph 20.5). Light these areas with "parking lot" type lighting.

7-10 CAR INTERCHANGE.

7-10.1 Purpose.

The interchange area or yard consists of one or more tracks used for the transfer of cars between the installation's railroad and the connecting commercial railroad. These tracks are usually located at or near the junction of the two railroads.

7-10.2 Arrangement.

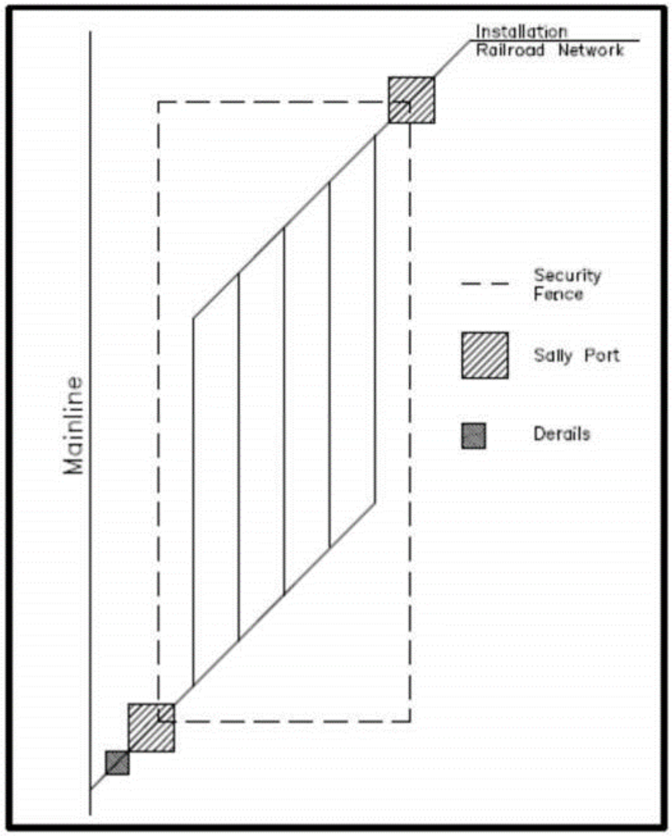
Figure 7-8 shows an example car interchange yard. In this arrangement, one or both of the outer two tracks would normally be designated as a running track and left clear of cars. The other tracks would be of sufficient combined length to handle the largest expected number of cars to come in or go out at any one time.

7-10.3 Running Track.

An open running track through the interchange yard will allow the installation's or commercial railroad's engine access to either end of each interchange track, and otherwise leaves an unblocked connection between the two railroads. The running track can also be used temporarily for switching. This makes it easier to rearrange the cars, if needed, or to pull out selected cars from any track.

At installations with frequent grade crossings or where at least one heavily traveled road crosses the tracks at grade, especially if the crossing angle is less than 45 degrees, access to either end of a cut of cars is usually required. This will permit the engine to always be at the front of a train, pulling the cars rather than pushing, in either direction of travel, providing much better visibility and safety at road crossings.

Figure 7-8 Interchange Yard



7-10.4 Set Out Track.

Consider including an additional track (or perhaps a short spur) at an interchange yard for special over-size loads, for cars needing repair, or for other special movements that need separate handling.

7-10.5 Derails.

In addition to being good practice, the connecting railroad will usually require that a derail be placed on the track leading to its line, along with a sufficient safe length of track between the derail and the junction. The derail is intended to prevent cars from accidentally rolling onto or blocking the connecting railroad's track. In some instances, derails are desirable at the installation end of the interchange tracks.

While derails themselves are not a design issue, their location is. Without a sufficient length of track between a derail and the clearance point of the track being protected, a derail will be nearly useless. During design, allow for this safe track length as an addition to the length of track required for car holding and switching space. The safe track length needed past a derail will vary with the grade of the yard tracks and the configuration of the junction area. Consult the connecting commercial railroad's engineering department for guidance on placing a derail to protect their track.

7-10.6 Security.

If the interchange yard is outside the main installation area or otherwise not located within constant view, it is recommended that the area be completely enclosed with a security fence, including lockable gates across the tracks (see Chapter 5, Paragraph 20.5). Consider lighting and guard towers if security-sensitive cargo is regularly handled.

7-11 YARD, STORAGE, AND OTHER AUXILIARY TRACKS.

7-11.1 Purpose.

Yard and storage tracks are intended for, respectively, the short and long-term holding of cars. Yard capacity is needed at least equal to the maximum number of cars that the installation is expected to handle at one time. Ensure the storage capacity, at a minimum, accommodates the number of cars to be kept at the installation over a longer term. Loading tracks are not considered available for storage unless cars are pre-positioned on them for loading.

Auxiliary tracks include sidings, wyes, balloon tracks, crossovers, tail tracks, and other tracks used for switching and maneuvering cars, allowing engines and cars to clear the main track for other movements (as in a second engine switching or delivering cars), or to allow an engine to get around the other side of a string of cars.

7-11.2 Yard Tracks.

Especially where the interchange with the commercial railroad is several miles from the loading sites, or where loading sites are within a separate secure area, a yard can be required. A yard is typically several parallel tracks, as in Figure 7-1, serving as a holding area for cars waiting to be loaded or delivered to the interchange area.

An example is an installation with a mobilization plan calling for 60 loaded cars to be picked up each day and 60 empties to be delivered by the commercial railroad, and with loading sites 12 miles (19.3 km) from the interchange point that can accommodate 30 cars at one time. This installation will likely need a yard that will hold at least the second 30 cars waiting to be loaded, and subsequently, the first 30 after they are loaded — to make room for the second 30 at the loading sites.

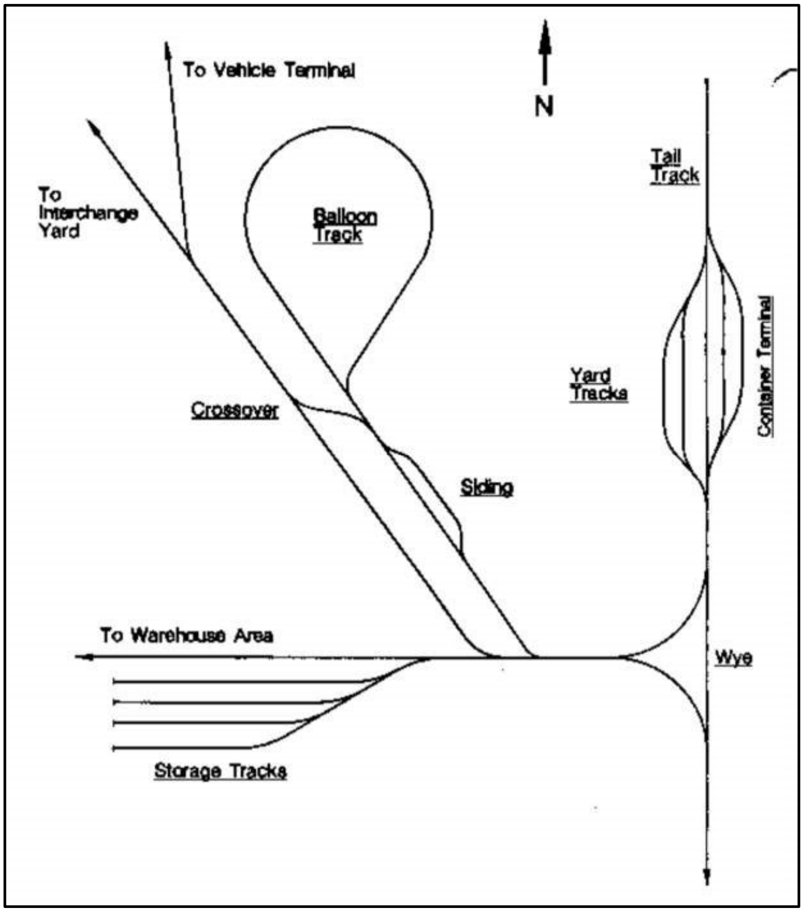
7-11.3 Storage Tracks.

Storage tracks or a storage yard can appear as shown in Figure 7-1 but are often designed as spur (dead end) tracks off a single ladder, as indicated in Figure 7-2 and the lower left corner of Figure 7-9. It is usually not essential to have access to either end of cars in storage, thus saving the cost and maintenance of turnouts at one end of storage tracks.

7-11.4 Auxiliary Tracks.

Figure 7-9 shows common auxiliary tracks. Their application is explained below.

Figure 7-9 Auxiliary Tracks



7-11.4.1 Sidings.

Sidings temporarily hold extra cars or part of a string of cars while the remainder are switched or allow an engine to bypass a string of cars.

7-11.4.2 Crossovers.

Crossovers can be used as a shortcut between routes or to allow an engine to get around a string of cars. In Figure 7-9, the crossover, for example, allows trains from the interchange yard access to the siding without having to go south to the warehouse track and then back north again, thus the crossover allows the siding to be conveniently used from either track. In addition, when handling a string of cars longer than the capacity of the siding, the cars can remain south of the crossover on either track, with the engine then using the crossover to get to the other track and then around to the opposite end of the cars.

7-11.4.3 Wye or Balloon Track.

At least one wye or balloon track is almost always needed at military installations. These tracks allow engines and cars to be turned around. This capability is required for most effective use of vehicle terminals. If cars are delivered to the installation such that the vehicles on them would be facing away (backward) from the loading ramps, the cars need to be turned so the vehicles can be driven in a forward direction off the cars. Of the two types of turning tracks, wyes are most common, as they require far less space than balloon tracks. Balloon tracks are typically used if space allows them to conveniently encircle other facilities, thus not requiring a large land area just for the balloon track. Balloon tracks have the advantages over wyes of requiring only one turnout and a single movement to accomplish the turn. Wyes require a backward movement to complete a turn, as well as throwing more switches. Wyes are often created by installing the third leg where a junction already exists (or is required). In Figure 7-9, for example, the wye also allows convenient access to the warehouse track from either north or south directions.

7-11.4.4 Yard or Siding.

When a yard or siding is located near the end of a route, a tail track is often added to allow switching from the far end of the yard or siding. A tail track is most useful if it is at least three car lengths longer than the siding or the longest track in the yard. Figure 7-9 shows a tail track north of the container terminal.

7-12 MISCELLANEOUS BUILDINGS.

7-12.1 Purpose.

Evaluate if buildings are needed for storage, shelter, and for other purposes in each terminal area. At vehicle terminals, a railyard operations building is needed for blocking and bracing storage.

7-12.2 Railyard Operations Building.

Consider the following when designing a railyard operations building:

- Locate as close to the loading area as possible without interfering with the flow of vehicles between the staging areas and the loading ramps.
- Sufficient space to accommodate the billeting of a rail loading crew.
- A communication system for enhanced command and control.

7-12.3 Blocking and Bracing Storage Facility.

Consider the following when designing a blocking and bracing storage facility:

- Locate as close to the loading tracks as possible. Determine if co-location with the railyard operations building is desirable.

- Sufficient size to accommodate blocking and bracing material required for one cycle of rail loading, that is, enough material for the maximum car capacity of the terminal.

APPENDIX A BEST PRACTICES

A-1 ROUTE SELECTION.

A-1.1 Introduction.

This chapter describes the process of selecting the route for the track connecting the terminal facilities with the commercial railroad serving the installation.

The location process begins by roughly defining potential routes or areas through which a railroad might practically run. Additional and more detailed information is then collected, and the route alternatives are gradually reduced until the final route is chosen. Before this process begins, complete the initial location and orientation of terminal facilities as described in Chapter 7.

The ideal route is usually the one that:

- Is shortest in length.
- Has the lowest grades.
- Has the least curvature.
- Costs the least to build.
- Most conveniently serves the installation and all terminal areas, as well as connecting railroads.
- Causes the least interference with other activities and modes of transportation.
- Is environmentally compatible with adjacent land use.
- Provides reliability for use in all weather conditions.

Since the above-listed objectives often conflict, the engineer’s job is to determine the appropriate compromises that will produce the best route under the circumstances – the one that best meets all objectives.

If initial line locations prove unsatisfactory in some important aspect, look for a different terminal location or re-orient a terminal so that the line serves it from a different direction.

Throughout the route selection process, it is essential to have good maps, including contour maps, of the area for the potential railroad line. These are often available from online sources.

A-1.2 Establishing Control Points and Potential Corridors.

Control points serve to limit location alternatives. They represent places through which the railroad must pass or would ideally pass. The most obvious control points are end points: the terminals and the connections with the commercial railroad. Establish intermediate control points, which can include facilities or geographic features that must be avoided, such as firing ranges, poorly drained areas, or environmentally sensitive areas. Place control points that also offer significant construction and operating advantages, such as narrow or shallow river crossings and areas with naturally good drainage. After control points are marked on contour or aerial maps, sketch approximate boundaries of potential route corridors. Identify more control points, and other information needed to define a specific route, during the next stage (reconnaissance).

A-1.3 Reconnaissance.

The reconnaissance is a quick examination of a wide strip of land between control points – the strip representing rough boundaries of a potential line location. If appropriate, examine several potential routes or alternatives for portions of a route.

The purpose of a reconnaissance is to identify routes that might allow the easiest construction effort consistent with the purpose and requirements of the railroad.

Contour maps, available geographic information system (GIS) information from county, state, and installation sources, aerial photographs from online sources, and previous survey information are good sources to use during the reconnaissance. A small set of maps and diagrams, with control points and potential routes identified, is convenient for field use. The information gathered during the reconnaissance can then be transferred to larger maps and computer files back in the office.

Perform reconnaissance by any means appropriate for the terrain and distances to be covered: review of online maps and photography, walking, driving, or from the air. Generally, take note of terrain features and anything that might affect route location and construction. Look especially for:

- Landmarks for referencing the location.
- Additional control points.
- Areas of potentially easy or difficult construction.
- Roads and utility lines to be crossed.
- Waterways or ravines to be crossed. Estimate length and height of bridges.
- Drainage paths.
- Soil conditions and geological features.
- Vegetation type and density.
- Potential for future additions to the railroad, as per the installation master plan.
- Wetlands and other environmentally sensitive areas.
- Snowfall and exposure to drifting snow.

Observe snow conditions along the proposed routes for at least one winter to identify locations where drifts form. Winter aerial photographs are potentially helpful for this purpose. Avoid sites downwind of frozen lakes unless there is adequate room between the shore and the roadway to install snow fences.

After the reconnaissance has been completed, prepare maps showing all control points and potential alternative routes. Then, make general comparisons between the routes with respect to length, grades, curvature, relative amount of earthwork and drainage work required, bridge work, special construction requirements, and potential operating advantages and disadvantages.

If sufficient information is available at this point, recommend the best route; otherwise, prioritize the routes. Also note any special requirements for the initial survey.

A-1.4 Initial Survey.

The objective of the initial survey is to obtain sufficient information to allow preparation of initial earthwork and construction estimates and to establish a location for the track and drainage paths on maps back at the office. When the route choice is clear from the reconnaissance, the initial and final surveys are often combined.

The initial survey is done by approximating the routes as a series of tangents, taking elevations and cross section data at selected intervals, perhaps every 100 to 250 ft. (30.5 to 76.2 m) along the route. Generally, where terrain is fairly uniform, the longer survey intervals can be used. Take elevations and cross section data at points representing a rapid change in terrain or at other points of special interest that aid construction estimating. Incorporate all useful landmarks into the survey. Stakes need to be driven in sufficient number to clearly show the survey centerline - about every 200 to 400 ft. (61 to 121.9 m).

For cross sections (nearby elevations at right angles to the route), simply take elevations at points that will show the shape of the adjacent terrain - local peaks, low points, and other points of special interest. The width of the required cross section will be dictated by the character of the terrain, right-of-way ownership, and distance needed to show local drainage and topographical features. It is not necessary for cross sections to be of equal distance on each side of the route centerline or of equal width at each station along the route.

Where terrain is open and easily accessible, cross section data is often taken from 300 to 500 ft (91.4 to 152.4 m) on each side of the route centerline. In areas where the route location is fairly well defined, cross sections are much narrower; sometimes only a 50-ft (15.2 m) wide strip is needed. The situation governs the choice of width.

When approaching points where a change in direction will occur, it will often prove useful to take an extra wide cross section on the inside of the angle, as a curve must eventually connect the two tangents through this area.

During the initial survey, be sure to take sufficient information to establish drainage paths on both sides of the track. Also note paths that drain runoff into the right-of-way as well as outlets where water can exit the right-of-way to nearby streams, drop inlets, or other runoff channels.

A-1.5 Trial Location.

Trial location is the process of determining potentially practical routes (trial routes) through a particular area. The objective of trial location is to produce the best combination of tangents, curves, and grades for the routes surveyed. This is done by combining survey information with design and economic guidelines, operating requirements, and engineering judgment. During this process, many factors must be weighed and prioritized, and conflicting objectives must be balanced.

After the first trial routes are located, construction estimates are made. Then, the location of the track or drainage path is usually modified in an attempt to reduce construction cost, while still maintaining satisfactory operating characteristics, or to improve operating characteristics while keeping construction costs at a reasonable level. Adjustments are made to each route until the most satisfactory set of compromises has been produced.

For track through an installation or in a terminal area, this process can usually be simplified and done with fewer iterations. Likewise, the construction estimates might be done only once.

Trial location begins by lightly sketching the boundaries of the initial survey on a contour map. The first trial route drawn through this strip is often done by minimizing grades, or in flatter territory, by minimizing the number of curves needed. As with the initial survey, the route begins as a series of connected tangents, with curves chosen and drawn in later.

After the route is sketched, a profile is drawn. The elevations of the railroad come from the elevations of end and intermediate points and the different grades chosen between these points. The elevations of existing ground level are obtained by approximating the point where the route would pass through each cross section taken in the initial survey. When an initial survey is not done, the ground elevations are taken from the points where the route crosses map contours.

With the trial routes drawn, earthwork and construction estimates are made using standard procedures. At this stage, estimate embankment and cut widths and slope angles using the typical roadway cross sections in Chapter 5, Paragraph 1. If one route does not yet appear clearly superior, generate an additional iteration of modifications and analysis to produce the final location.

A-1.6 Final Location.

To finalize the route selection, modify the trial routes, if necessary, to even cut and fill amounts in adjacent areas or to reduce the total earthwork and grading required.

Where grades or curvature exceed the most desirable limits, the routes should be modified, if feasible, to reduce these. Also review the criteria listed in Paragraph A-1.1, for each trial route.

APPENDIX B RULING GRADE – EXAMPLE PROBLEM

This example of determining a trial ruling grade for a new railroad line follows the material presented in Chapter 3, Paragraphs 4, 5, and 6.

A railroad line is to be built from the terminal serving the new training area at Fort Example to the nearest commercial railroad, about 15 miles away. The most critical traffic, and heaviest loads, will be M-1 tanks on flatcars. Each car is 70 feet long and has a maximum loaded weight of 187 tons riding on 6 axles. The installation has one 1,500 HP, 100-ton locomotive.

To handle movements during larger training exercises and mobilization, the installation wants to use an engine from the connecting railroad which will be capable of hauling 25 loaded flats over the line at 15 MPH minimum speed. The connecting railroad expects to have a 3,000 HP, 170 ton (340,000 pound) locomotive available when needed. Tractive effort curves are not available for either locomotive. For simplicity, let locomotive length equal car length.

The designer must now determine the maximum effective gradient and grade length on the new line to accommodate these train movements. The first step is to determine how much traction force is available using Chapter 3, Paragraph 5.4. Available traction force will be the lesser of locomotive tractive effort or traction at the wheel-rail adhesion limit, for the commercial locomotive:

1. Locomotive Tractive Effort at 15 MPH = 300 x 3,000 / 15 = 60,000 lbs.
   Wheel-Rail Traction Limit = 340,000 / 4 = 85,000 lbs.
2. Locomotive traction capability governs usable tractive effort.
3. Ruling Grade from Equation 3-3:

   TE =60,000 lbs

   W_{eng} = 170 tons

   W_{car} = 187 tons

   N_{car} = 25

   G = 60,000 / 20(170 + 25 x 187) - 0.15

   = 0.47%

   Grade length = 26 (engine and cars) x 70 = 1820 Feet (or longer)

Thus, grades of 1820 feet or longer would have to be limited to an effective gradient of 0.47%. After a brief review of contour maps of the proposed route, the designer believes the route requires grades much steeper than 0.47% to keep construction costs at an acceptable level.

One way to accommodate the desire to move single trains of 25 loaded flats at a minimum speed of 15 MPH and allow for a steeper ruling grade is to use the installation's engine and commercial engine together. Dropping the travel speed up the ruling grade to 10 mph further increases the tractive effort available. To offset the loss in speed up the ruling grade, other portions of the route might be constructed to accommodate higher speeds perhaps – 25 to 30 mph. A check of this possibility shows the following:

For the commercial locomotive:

1. Traction at the Adhesion Limit = 340,000 / 4 = 85,000 lbs.
2. Locomotive Tractive Effort at 10 MPH = 300 x 3,000 / 10 = 90,000 lbs.
    a. Wheel-rail adhesion governs usable tractive effort.

For the installation's locomotive:

1. Traction at the Adhesion Limit = 200,000 / 4 = 50,000 lbs.
2. Locomotive Tractive Effort at 10 MPH = 300 x 1,500 / 10 = 45,000 lbs.
    a. Engine power governs usable tractive effort.
3. Ruling Grade (from Equation 3-3):

    TE =85,000 + 45,000 = 130,000 lbs.

    W_{eng} = 170 + 100 = 270 tons

    W_{car} = 187 tons

    N_{car} = 25

    G = 130,000 / 20(270 + 25 x 187) - 0.15

    = 1.16%
4. 2 engines and 25 cars = 27 total

    Grade length = 27 x 70 = 1890 Feet (or longer)

Thus, if this revised arrangement is acceptable, grades of 1890 feet or longer could have an effective gradient as high as 1.16%. Table B-1 shows the curve compensation for curves on this grade.

Table B-1 Curve Compensation for a 1.16% Grade

Degree of Curve	Uncompensated Grade		Compensated Grade	
	Actual	Effective	Actual	Effective
1	1.16	1.20	1.12	1.16
2	1.16	1.24	1.08	1.16
3	1.16	1.28	1.04	1.16
4	1.16	1.32	1.00	1.16
5	1.16	1.36	0.96	1.16
6	1.16	1.40	0.92	1.16

From the table, if a 5 degree curve was located within the ruling grade, the constructed (actual) gradient through that curve must be limited to 0.96% to keep the effective gradient within 1.16%.

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APPENDIX C SAMPLE TRACK REHABILITATION REPORT

This sample report illustrates the type of information and level of detail suggested for an analysis of a military railroad network in preparation for rehabilitation work. The material that explains how the work is normally conducted is included for the benefit of the reader and would not be necessary in an actual rehabilitation plan.

Included in this example report are:

1. A description of track and roadway condition.
2. A problem/defect analysis.
3. A sequential work plan to correct the defects.
4. Cost estimates for each item of the work plan.

The material in Appendix C covers the structural evaluation that is normally required in a rehabilitation plan. Follow the guidance in Chapter 4, Paragraph 5 for the operational evaluation, which is not detailed here. Please note, do not use costs shown in the sample report as they are out-of-date.

RAILROAD TRACK REHABILITATION REPORT FOR FORT EXAMPLE

SUMMARY

Examination of the railroad network at Fort Example showed the following major deficiencies:

1. Inadequate lateral and longitudinal track stability.
2. Deteriorated track through road crossings.
3. Turnout defects.
4. Washouts under track.
5. Defective and/or skewed ties in certain areas.
6. Loose or missing track fastenings.
7. Thick vegetation growing in some portions of track.

The work plan was divided into 2 phases, with a total project cost of approximately $970,000.

Phase 1, to be accomplished first, covers the rehabilitation of the primary route and sidings extending from the connection with the commercial railroad to the end of the East Line. This work is estimated to cost approximately $550,000.

Phase 2 covers rehabilitation of most of the remainder of the track network: the south half of the Main Line, the West Line, and the North Line. This work is estimated to cost approximately $420,000.

The remedial work described in this report would restore the railroad network to a fully functional level, in a cost-effective manner. Remedial work has been specified only for those sections of track where the work is most needed. Tracks with no current use are not included in the plan.

The work plan has been designed so that when completed, the railroad network would require only normal routine maintenance to keep it fully functional for the foreseeable future.

C-1 INTRODUCTION.

C-1.1 Background.

This rehabilitation plan was prompted by reports that portions of the Fort Example railroad network were in a general deteriorated condition and that results of the structural evaluation program indicated structural deficiencies in several stretches of track. These conditions were confirmed by the team performing the track assessment contained in this report.

C-1.2 Objectives.

The objectives of this report are to:

1. Document the track and roadway deficiencies found during the recent field inspection, both by type and extent.
2. Propose corrective measures.
3. Provide cost estimates for budget planning.

The corrective work included in the plan is intended to restore the railroad network in a cost-effective manner. Thus, not all sections of track in the network are included in the plan, and each type of remedial work is specified only for those sections most in need. Further, corrective work is specified only to the extent that will restore the long-term function of the track. Tie replacement estimates are based on improving tie condition to the point where installation trackage can function well for 5 years before the next tie replacement program is needed.

C-1.3 Approach.

A three-person team visited the installation to examine the railroad network. During this visit, all track (except the short piece leading to the old coal/gravel chute) was examined by walking inspection, and all primary routes were traveled with the installation’s 120-ton locomotive. In addition, those who were familiar with the track were interviewed about deficiencies they had observed and about track work performed in recent years.

C-1.4 Scope.

This report is intended to assist in the preparation of contract specifications for remedial track work. Neither the field investigation nor this report is intended to cover every detail required for proper restoration of the railroad network, nor is this report intended to be a substitute for a complete statement of work and specifications. There are, in fact, several items noted that will require additional examination and decisions before a complete and final remedial work plan can be established.

Accompanying this report are both general and detailed track maps and photographs, with notes, showing portions of the railroad network and representative defects.

C-2 OPERATIONAL EVALUATION.

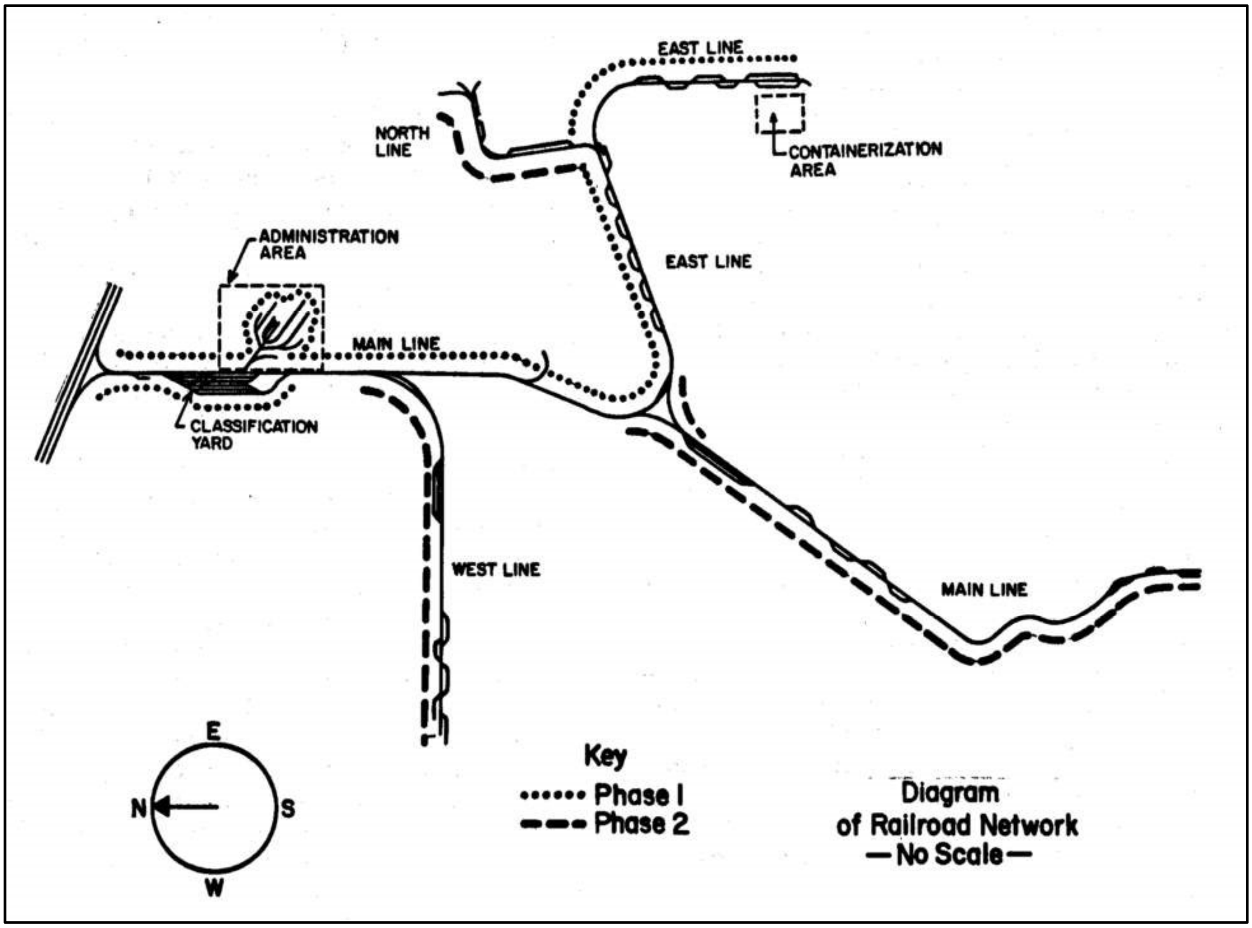
Operational evaluations are covered according to the guidance in Chapter 4, Paragraph 5.

C-3 DESCRIPTION OF NETWORK AND TRACK CONDITION.

C-3.1 Introduction.

The railroad network connects with the [__________] Railway about 10 miles east of (City), (State). Of the 19.95 miles of track, 9.62 miles are primary routes, 3.43 miles are in the classification yard, and 6.90 miles are loading and storage sidings and auxiliary tracks. A track diagram is shown in Figure C-1, with a key to track designations in Table C-1.

Figure C-1 Track Diagram for Fort Example



Incoming cars are generally brought to the classification yard by the commercial railroad. There, one of the two installation locomotives will pick up the cars and deliver them to the appropriate area for loading or unloading. These cars are then brought back to the yard for pick up by the commercial railroad.

Table C-1 Key to Track Names and Station Locations

Letter Prefix	Track Type or Area
M	Main Line
E	East Line
W	West Line
N	North Line
A	Administration Area
P	Sidings serving loading ramps
S	Sidings serving buildings A through L
X	Miscellaneous spurs or sidings
Y	Wye tracks
2-14	Tracks in the Classification Yard

Below is a description of the railroad network, by component, reflecting conditions found during the investigation.

C-3.2 Rail.

C-3.2.1 Description.

80 percent of the rail is 90 lb (weight per yard of length) and manufactured between 1909 and 1924. The remaining 20 percent is 85 lb. The 85 lb. rail is primarily in Tracks 4 through 14 of the classification yard, the end of the North Line, and on Track A5 in the Administration Area, leading to the engine house. All rail was manufactured before the control cooling process was in use. The control cooling process, now standard practice, greatly reduces the formation of internal defects.

C-3.2.2 General Condition.

The rail is generally in good condition, neither excessively nor unevenly worn. Very few pieces show serious end batter or surface bending. Likewise, obvious external defects, serious corrosion (except, perhaps in crossings - where the whole rail is not visible), and breaks are rare. Testing for internal rail defects was not done.

C-3.3 Plates/Fastening.

C-3.3.1 Plates.

Almost all track has single shoulder tie plates. These are in adequate condition, with relatively few missing or defective.

C-3.3.2 Joints.

Joint bars are in good condition, with few excessively worn, cracked, or broken. However, many bolts are missing, loose, or not fully tightened. Of those that are not fully tightened, many appear to be rusted solid with the nut.

C-3.3.3 Spikes.

Spikes are in good condition; however some are not fully driven or have worked their way up in the last few years. Also, spikes have been frequently driven through angle bar base slots, which is no longer considered to be good practice.

C-3.4 Ties.

C-3.4.1 Description.

Most older ties are 6 x 8-in. in cross section. Most of the ties installed during the tie replacement 8 years ago are 7 x 8-in.

C-3.4.2 General Condition.

Tie condition is generally fair to good. Areas that did not receive ties during the last tie replacement program are generally in the worst condition. On the Main Line, approximately between stations 200+00 and 250+00, there are many skewed, bunched, or otherwise improperly spaced ties.

C-3.5 Ballast.

C-3.5.1 Description.

Most track in the primary routes has ballast composed of a low density, finely crushed volcanic material or slag, or cinders mixed with earth. Some stretches of track appear to have no real ballast section, leaving the track essentially sitting directly on the subgrade.

During recent track work, some new ballast was applied. This ballast is crushed rock of about AREMA 3 or 4 gradation and appears to be good, hard material. However, in most cases, this ballast is only a surface treatment, helping to fill in cribs (the spaces between the ties) and fill out the shoulders (at the ends of the ties).

C-3.5.2 General Condition.

The cinder/volcanic/earth material seems to drain adequately, but apparently provides insufficient lateral or longitudinal stability to the track. See Track Geometry section below. Additionally, this material is not sufficiently dense and stable to resist washout from heavy rains. See Drainage/Subgrade section below.

C-3.6 Drainage/Subgrade.

C-3.6.1 Description.

While the rainfall in this area of the country is not high, much of the rain comes in short, heavy periods, resulting in flash floods and washouts. Culverts at the installation are generally large, as big as 72 in., and often of double pipe arrangement, not only to accommodate sudden heavy flows, but also the debris that is swept along by the water.

The track is built on a sandy subgrade and is generally elevated above surrounding ground level. There are, however, clay layers near the surface in some locations. The large, flat areas containing tracks in the classification yard and in the Administration Area do not have a subdrainage system.

C-3.6.2 General Condition.

Drainage is generally good, both from the track and through culverts. However, there are a few problem areas. After a heavy rain, water commonly stands in the Administration Area and in some loading sidings for quite some time. Also, due to the large amount of debris present in the storm runoff, some culverts are partially or fully blocked.

Heavy rains have also caused several small washouts on the Main Line, especially along a roughly 800-ft stretch between stations 162+00 and 170+00 and at the south end of the line. In some places, shallow clay seams block vertical drainage, but water can usually escape adequately in lateral directions. And despite the numerous loose joint bars, the number of low joints is quite small, indicating good vertical ballast and subgrade support.

C-3.7 Vegetation.

C-3.7.1 Description.

Thick brush and low vegetation grow close to the track in many stretches of track, especially in loading sidings and near the ends of the primary routes.

C-3.7.2 General Condition.

Some vegetation is very tough, and where dense growth occurs, it scrapes the sides of trains. Because of this growth, it is difficult for a person to walk next to the track in several loading sidings and at the end of the Main Line.

C-3.8 Turnouts.

C-3.8.1 Description.

Turnouts are either 85 or 90 lb, matching the rail in the adjacent track. All but a few are Number 8 (in size) and have bolted frogs and either 11-ft or 16 ft, 6-in. switch points.

C-3.8.2 General Condition.

Overall, turnout condition, line, and surface are adequate. However, many switches are difficult to operate and badly need cleaning, lubrication, and adjustment. At many switches, the heel bolts are loose and the nuts and bolts often appear solidly rusted together, which would prevent re-tightening. Some switch points are also badly chipped or broken, and other miscellaneous parts need replacement. About half the turnouts had most or all of their ties replaced during the last tie replacement program. A few turnouts that did not get new ties do need some new ones.

C-3.9 Road Crossings.

C-3.9.1 Description.

Most crossings are all asphalt, with a few gravel/dirt type. There are two rubber crossings through the Main Highway near the connection with the commercial railroad.

C-3.9.2 General Condition.

About 25 percent of the asphalt crossings are in fair to poor condition. Likewise, the track in those crossings appears to be in fair to poor condition, typically showing loose joints and wide gage. Through a few crossings, only the slow and careful operation by the installation train crews has prevented derailments from occurring.

C-3.10 Track Geometry.

C-3.10.1 Description.

Track geometry describes the relative position of the two rails and track in the vertical and horizontal planes. The three primary measurements are:

- Alignment - a measure of lateral track deviations.
- Surface/Cross level - measures of vertical track deviations.
- Gage - the spacing between the two rails. Standard Gage is 56-1/2 in.

C-3.10.2 General Condition.

C-3.10.2.1 Alignment.

Track alignment is generally fair, with some poor sections.

C-3.10.2.2 Surface/Cross Level.

Track surface is generally adequate, although poor in places on the east half of the East Line, west half of the West Line, and spots on the Main Line. Track surface is also poor in some loading sidings. A few curves have excessive superelevation.

C-3.10.2.3 Gage.

Track gage is generally good, with the exception of some of the road crossings, where wide gage is common, and spots where skewed ties have caused tight gage.

C-3.11 Bridges.

C-3.11.1 Description.

There are three all timber bridges:

Table C-1 Timber Bridges

Line	Location	Length	Deck Type
Main	19+13	64 ft	Open
West	9+02	85 ft	Ballast
	40+00	122 ft	Open

C-3.11.2 General Condition.

These bridges were thoroughly inspected about 2 years previously and found to be in good condition. During this visit, the bridges were given a brief inspection, and no obvious defects were apparent.

C-4 STRUCTURAL ANALYSIS.

Explain any computer program or structural evaluations here.

C-5 ANALYSIS OF MAJOR DEFICIENCIES.

Below is a description of the major track deficiencies, along with contributing factors, where appropriate. In addition, these deficiencies refer to the remedial actions, as described in Paragraph C-6, designed to correct them.

C-5.1 Inadequate Lateral and Longitudinal Track Stability.

The track at the installation has at best, a surface layer of crushed rock ballast. Most stretches have a low density mix of fine crushed volcanic material and earth filling in the spaces between and around the ties. This material does not provide adequate lateral or longitudinal track support. And as a result, track alignment is generally fair or poor, and many ties have shifted position and become skewed (not perpendicular to the rails).

To both restore and keep proper track line and surface and maintain proper tie position, a sufficient amount of good quality ballast material must be added to the track. In addition, anchors must be correctly re-applied and added where needed. Remedial Actions 2, 6, 8, 9, 12, and 13 (as listed in Table C-2) are designed to establish adequate lateral and longitudinal track stability.

C-5.2 Deteriorated Track Through Road Crossings.

About 25 percent of the asphalt crossings are in poor condition, and likewise, so is the track in them; ties have deteriorated, track support is mushy, and joints have loosened - in some cases allowing track gage to widen to an unsafe distance. Remedial Action 5 includes complete crossing/track rebuild, as required.

C-5.3 Turnout Defects.

The portion of the track covered by this rehabilitation plan includes 48 turnouts. Many of these are difficult to operate, out of adjustment, and have loose or defective parts. Remedial Action 9, Restore Turnouts, includes allowances for general turnout rehabilitation.

C-5.4 Washouts under the Track.

Heavy rain runoff occasionally washes out ballast and subgrade beneath the track in three areas along the Main Line. Nine small washes have occurred in the last 3 years in the Main Line between Sta. 162+80 and 169+70. One small washout occurred near Sta. 253+40, and a deeper washout just past that point. This is one area in which further study will be required to determine the most cost effective way to either eliminate the probability of future washouts, or at least minimize possible track damage. Remedial Action 2 includes a general plan for correcting drainage problems at these washout areas.

C-5.5 Skewed Ties.

Some areas of the Main Line (mostly between stations 200+00 and 250+00) have skewed (crooked), bunched, and misspaced ties. This situation is caused by the following:

- Low density ballast that cannot resist tie movement.
- Cribs (space between the ties) not fully filled with ballast, further reducing resistance to tie movement.
- Anchors not replaced after tie installation or applied to only one rail (one side of the tie).
- Track on grades. Portions of the track are on grades steep enough to encourage longitudinal rail movement, and thus also, tie movement.
- Spikes driven in the slots in angle bar type joint bars. This is no longer considered good practice. As joints are usually staggered, rarely does a tie ever have a joint on both rails. Driving spikes into the joint bar base slots will then have the same effect as anchoring only one side of a tie.
- Ties with incorrect spiking pattern, present in some of the older ties. While this incorrect pattern does not actually cause tie skewing, it does encourage it.

- Some ties appeared to have been installed crooked.

Remedial Action 7 provides for repositioning skewed and misspaced ties, and Remedial Action 10 will help prevent future tie movement.

C-5.6 Loose or Missing Track Fastenings.

Numerous rail joints have loose or missing bolts, and at least 12 joints noted during the inspection have both bolts in one rail missing. Remedial Action 8 calls for tightening all joints and replacing defective bolts and joint bars.

C-5.7 Vegetation In or Near the Track.

Scattered locations along primary routes and loading sidings have thick brush growing close to the track, and in some cases, in the ballast section. This vegetation must be removed before any track work can be performed. In addition, sufficient herbicide needs to be applied soon after completion of track work to prevent future brush growth. Remedial Actions 1 and 13 cover the removal and future prevention of brush growth.

C-6 RECOMMENDATIONS AND COST ESTIMATES FOR REMEDIAL WORK.

C-6.1 General.

This section presents a general plan for correcting the majority of track deficiencies. The plan is organized as a list of 14 remedial actions, numbered in general work sequence order. The cost estimates for each remedial action are broken down between Phase 1, to be done this year, and Phase 2, to be done next year. Table C-2 shows a cost estimate summary.

Table C-2 Cost Estimate Summary

REMEDIAL ACTION				
No.	**Description**	**PHASE 1**	**PHASE 2**	**TOTAL**
1.	Remove Vegetation	$ 1,200	$2,400	$3,600
2.	Restore Drainage	15,000	35,000	50,000
3.	Rail Defect Inspection	5,000	---	5,000
4.	Replace Defective Rail	13,600	13,600	27,200
5.	Rebuild Crossings	29,950	33,470	63,420
6.	Tie Replacement	140,000	100,000	240,000
7.	Respace Ties	3,250	8,125	11,375
8.	Tighten Bolts/Spikes	18,700	18,700	37,400
9.	Restore Turnouts	19,800	12,150	31,950
10.	Rail Anchors	33,580	25,200	58,780
11.	Unload Ballast	147,640	86,060	233,700
12.	Surface Track	55,200	32,175	87,375
13.	Herbicide Application	3,200	2,600	5,800
14.	On-Site Inspection	12,000	12,000	24,000
	Subtotal	$498,100	$381,500	$879,600
	10% Contingency	49,810	38,150	87,960
	TOTAL	$547,910	$419,650	$967,560

NOTES:

PHASE 1 covers the primary route from connection with the commercial railroad to the end of the East Line, Admin. Area, and Tracks 2-5 of the Classification Yard.

PHASE 2 covers the remainder of the Main Line (East Jct. to End), West Line, and North Line.

Phase 1 and Phase 2 include the following trackage:

a. Phase 1: Main Line from connection with the commercial railroad (Sta. 0+00) to East Junction (Sta. 119+81).
    - Track Y1 and Classification Yard tracks 2 – 5.
    - Administration Area tracks A1 – A8.
    - East Line and sidings from Origin (Sta. 0+00) to End (Sta. 120+56).

b. Phase 2: Main Line and sidings from East Junction (Sta. 119+81) to End (Sta. 263+97), and track Y2.

- West Line and sidings from Origin (Sta. 0+00) to End (Sta. 75+06).
- North Line and sidings from Origin (Sta. 0+00) to End (Sta. 47+96).

The work plan and estimates are for restoration of the majority of the railroad network. However, not all remedial actions are intended to be carried out on all trackage. Within the description of each remedial action, the intended work limits are listed, where appropriate.

Generally not included in the work plan are Classification Yard tracks 6-14 (the far west tracks), tracks X1 through X5, Administration Area track A9 (to the old coal/gravel chute), and track P5 (at the end of the West Line). These tracks, while required for mobilization, are not in regular use.

C-6.2 Remedial Actions.

A cost estimate summary of the remedial actions is shown in Table C-2.

C-6.2.1 Remove Vegetation.

The first step to ensure that the track is fully accessible for other track work and that large amounts of vegetation will not be buried in the track during ballast unloading is vegetation removal. Use a plow and brooms of a ballast regulator, supplemented by laborers with brush cutters to remove vegetation.

Phase	Mileage	$ Estimate
1	1.2	1,200
2	2.4	2,400
Total	3.6 mi	$3,600

Note: Unit Cost = $1,000/Mile

C-6.2.2 Restore Drainage.

It is essential that proper drainage be provided and maintained to prevent roadbed deterioration and track washouts. While drainage of the track network is mostly satisfactory, some general maintenance is needed, with a few areas that require serious attention. This section provides a rough allowance for the following drainage work:

- Excavator, dump trucks, backhoe, and laborers reshaping ditches and cleaning culverts.

- Grading in the Administration Area to keep water from standing within the roadbed.
- Installation of culverts and related earthwork in washout areas on the Main Line.

Due to the nature of the drainage in the Administration Area and in the washout areas, it is not practical to implement a solution that will entirely correct the problems. A plan that greatly improves the situation is recommended.

Especially after heavy rains (such as were experienced last summer), water stands in the track in the Administration Area. Apparently, a drainage system was never installed here, and providing one now is quite expensive.

It is recommended that consideration be given to at least providing some grading so that water will tend to flow away from the track into adjacent lowered areas. While this solution will not eliminate the standing water in this area, it could at least prevent it from standing in the track, where it would do the most damage.

In selected areas along the Main Line, especially between Sta. 162+80 and 169+70, ballast and subgrade have been washed out from beneath the track on several occasions. These areas are located in the natural drainage path of heavy rain runoff. While preventing all runoff from reaching the track is not be affordable, it is recommended that remedial work be considered that will at least prevent the water that does reach the track from causing any roadbed damage. Such work might include:

- Install a culvert, perhaps double pipe, beneath the track, at the center of the washout area. Grade adjacent area to channel water through the culvert. Place large rock near the culvert approach to prevent erosion.
- Construct an interceptor berm, or other obstacle, in the drainage path to break the force of a heavy runoff.
- Increase the ballast shoulder in the washout areas to 12 in. This provides additional resistance against damage by water that does reach the track.

Accomplish any drainage work that directly disturbs the track before track work begins.

Phase	$ Estimate
1	15,000
2	35,000
Total	$50,000

C-6.2.3 Internal Rail Defect Inspection.

Since no record of internal rail defect inspection exists, and all rail was manufactured before the use of controlled cooling (1933), an inspection for the presence of internal rail defects should be made over the entire railroad network.

Phase	Mileage	$ Estimate
1	17	5,000
2	---	---
Total	17 mi	$5,000

Note: Rail defect testing is priced per day plus travel costs, rather than by mileage. Phase 1 includes inspection of all track in the rehabilitation plan. In addition to cost effectiveness, inspection of all rail as soon as practical will permit an accurate determination of the quantity of rail that requires replacement.

C-6.2.4 Replace Defective Rail.

This estimate is an allowance for replacing the defective rails that may be found during an internal defect inspection.

Phase	Number of Rails	$ Estimate
1	34	13,600
2	34	13,600
Total	68	$27,200

Note: Unit Cost = $400/rail. Estimate based on 33-ft sections of 90 lb. rail, and allowance of four defective rails/mile.

C-6.2.5 Rebuild Road Crossings.

In road crossings that require replacement, the track often needs to be completely rebuilt. In addition, conventional rail joints are often replaced with welded joints to eliminate the need for future joint maintenance (which usually requires tearing out at least part of the crossing surface). Welding joints in a crossing is especially recommended in areas with heavy truck traffic and in crossings in main running tracks.

The rebuilding of crossings can start any time before the ballast and surfacing operations. These estimates cover crossing replacements, as listed in Table C-3. Three types are specified: complete track rebuild with timber/asphalt surface, timber/asphalt surface replacement, and timber/gravel surface replacement.

Table C-3 Road Crossing Repair/Rebuilding

Phase	Centerline Line	Crossing Location	Rebuild Length (ft)	Type
1	Main	24+53	24	CA
		77+55	42	CA
		113+65	87	CA
	East	10+94	33	A
		46+46	31	A
		65+81	30	CA
2	Main	173+20	25	A
		193+31	22	A
		204+20	15	G
		258+09	30	A
	West	4+45	18	G
		37+56	21	A
		45+49	19	A
	North	5+75	85	CA
		35+63	30	A
		44+95	67	CA

SUMMARY Phase	Rebuild Type	Number of Xings	Footage	Number of Welds
1	CA	4	183	7
A		2	64	4
2	CA	2	152	8
A		6	126	11
G		2	33	2

Rebuild Type Key

CA – Timber/Asphalt crossing surface with complete track rebuild.

A – Timber/Asphalt crossing surface replacement.

G – Timber/Gravel crossing surface replacement.

The timber portion of the crossing surface refers to timber head boards installed along the gage side (or both sides) of the of the rail. Timber head boards help keep the flangeways clear, reduce intrusion of road material into the track, and lessen the lateral rail impact from vehicle traffic.

Phase	$ Estimate
1	29,950
2	33,470
Total	$63,420

Note: The following are the unit costs used for crossing work:
Timber/Asphalt crossing with complete track rebuild, $125/foot.
Timber/Asphalt crossing surface replacement, $50/foot.
Timber/Gravel crossing surface replacement, $25/foot.
Joint welds, $350 each.

C-6.2.6 Tie Replacement.

This estimate provides for ties primarily in the areas that were not covered in the previous tie replacement program. Generally, the limits are the same as specified for ballast and surfacing. The number of ties estimated is intended to allow the installation track to maintain sufficient tie condition for 5 more years before another tie program is required. (Although during the next 5 years, some spot tie replacement will probably be needed).

Included in the estimate for each phase is an allowance for 400 ties in the loading tracks (and the containerization terminal on the East Line to be done in Phase 1) and for 100 ties that drop during surfacing and are in too poor a condition to be re-spiked.

Exact tie counts should be made when preparing the final plans.

Phase	Number of Rails	$ Estimate
1	3500	140,000
2	2500	100,000
Total	6000	$240,000

Note: Unit Cost = $40/tie.

The tie spacing at the installation averages 20 in., which equals 3,168 ties/mi.

C-6.2.7 Respace Ties.

During this remedial action, properly reposition all skewed and misspaced ties. This work also includes raising ties that dropped during the track raise and replacing occasional defective ties that cannot be re-spiked.

This estimate covers labor and machine costs for tie respacing.

Phase	Mileage	$ Estimate
1	2.5	3,250
2	6.25	8,125
Total	8.75 mi	$11,375

Note: Unit Cost = $1300/mi.

For Phase 2, tie respacing not required on Main Line from Sta. 154+00 to Sta. 200+00. This work is also only needed over approximately half of the North Line.

C-6.2.8 Tighten and Replace Track Bolts/Drive High Spikes.

Due to numerous loose rail joints, use a bolt tightening machine to tighten all track bolts. During this operation, replace all defective bolts and joint bars. Along with bolt tightening, drive down all high spikes and replace all defective spikes. This will minimize the number of ties that drop down when the track is raised during surfacing.

However, it is not recommended to either pull any spikes driven in the slots of angle bar type joint bars, or pull or add any spikes in ties with an incorrect spiking pattern. The combination of tie straightening/respacing, additional ballast, and application of rail anchors included in this rehabilitation plan will prevent future tie movement due to incorrect spiking. Further, there would be significant potential for long term tie damage due to pulling spikes (even if old holes are plugged).

Both operations (for bolts and spikes) should be performed prior to any ballast unloading or surfacing.

Phase	Mileage	$ Estimate
1	8.5	18,700
2	8.5	18,700
Total	17.0 mi	$37,400

Note: Unit Cost estimate of $2,200/Mile based on:

1. Bolt tightening, $1,500/mi.
2. Allowance for extra bolts, $2.50 each, 120 per mi, or $300/mi.
3. Allowance for extra spikes and miscellaneous work, spikes @ $1.00 each, total allowance @ $400/mi.

C-6.2.9 Restore Turnouts.

Table C-4 provides a detailed listing of turnouts included in Phases 1 and 2, along with a rough approximation of switch tie requirements and switch point replacements. (Determine exact requirements for inclusion in contract work statement).

Phase	Number of Turnouts	$ Estimate
1	10	19,800
2	12	12,150
Total	22	$31,950

Notes:

1. Unit Cost varies with work required. Estimates based on:

   a. $1050/turnout for surfacing, miscellaneous parts, and cleaning and adjustment.

   b. $50/switch tie, installed.

2. Estimate allows for 74 switch ties in Phase 1 and 126 in Phase 2. (See Table C-4).

3. Estimate allows for seven switch points to be replaced in Phase 1 and 6 in Phase 2. Cost per point (installed) is estimated to be about $800 for a 16 ft, 6-in. point.

Table C-4 Turnout Rehabilitation

Phase	Line	I.D. Number	Location	Direction	Switch Tie Requirement	(1) Point Replacement
1	MAIN	M03	24+67	RIGHT	8	L R
		M04	39+88	LEFT	--	R
		M05	40+21	LEFT	--	L R
		M07	44+84	LEFT	12	--
	EAST	E03	3+64	LEFT	10	--
		E04	14+49	LEFT	8	--
		E08	36+15	RIGHT	20	--
		E10	42+77	LEFT	8	--
		E12	49+60	RIGHT	8	--
		E17	117+95	LEFT	--	L R
					74	7
2	MAIN	M13	134+51	RIGHT	15	--
		M15	155+02	LEFT	5	--
		M16	162+11	LEFT	5	--
		M17	170+55	RIGHT	9	L R
	WEST	W09	69+23	RIGHT	8	L
		W11	70+89	LEFT	8	--
		W12	71+54	RIGHT	8	R
	NORTH	NO1	8+78	RIGHT	12	--
		NO4	23+03	LEFT	22	L
		NO5	25+80	RIGHT	11	L
		NO6 (1)	32+47	LEFT	9	--
		NO7 (2)	32+87	RIGHT	14	--
Notes:					126	6

L = Left Point, R = Right Point

1. One switch rod missing
2. Cracked frog

C-6.2.10 Apply Rail Anchors.

After new ties have been installed and skewed and misspaced ties properly repositioned, apply rail anchors.

This estimate calls for every fifth tie to be box anchored (have four anchors applied), with anchoring of primary routes only (no sidings). See Notes 2 and 3 below for intended anchoring limits.

Phase	Mileage	$ Estimate
1	4.77	33,580
2	3.58	25,200
Total	8.35 mi	$58,780

Notes:

1. Unit Cost estimate of $7,040/Mile, based on:
    a. Purchase cost of $2.00/anchor.
    b. Installation cost of $1.25/anchor.
    c. 2,560 anchors/mi.
    d. Assumption that 25 percent of required anchors can be salvaged from existing material.
2. For Phase 1, anchors are to be applied along the Main Line from Railroad connection (Sta. 0+00) to East Junction (Sta. 119+81); East Line from Origin (Sta. 0+00) to End (Sta. 120+56); and along Y1.
3. For Phase 2, anchors are to be applied along the Main Line from East Junction (Sta. 119+81) through Sta. 194+00; West Line from Origin (Sta. 0+00) through Sta. 70+89; and North Line from Origin (Sta. 0+00) through Sta. 43+63.
4. Recommended anchoring near the two open deck bridges (M 19+13 and W 40+00) is: no anchors on the bridge; box anchor every third tie for two rail lengths (about 66 ft) off either end of the bridge.

C-6.2.11 Unload Ballast.

Once the track is clear of excess vegetation, all bolts in place and tight, high spikes driven, and track in crossings rebuilt, the track is ready for new ballast to be applied. Ballast and surfacing locations are shown in Table C-5.

This estimate is for sufficient ballast to give the track a 3-in. raise, fill in shoulders and cribs, and pull up any track sags. It includes the costs of purchasing the ballast material, delivery to the work site, and distribution along the track.

Table C-5 Ballast and Surfacing Locations

Location	Footage
PHASE 1	
Main	
3+87 (S. end Rt. 40 Xing) to 19+13 (N. end bridge)	1,526
24+65 (S. end new Xing) to 45+50 (N. end scale track)	2,085
47+51 (S. end scale track) to 119+81 (East Junction)	7,230
	10,841
East	
0+00 (East Junction) to 120+56 (End)	12,056
Sidings (except X3, X4)	6,586
	18,642
Yard	
Tracks 2-5	5,823
Admin	
Track A1 - up to 5+61 (Building 9)	561
Track A5 - up to 14+40 (to engine house)	1,440
Track A6 - up to 9+52 (End)	952
Track A8 - up to 6+00 (to scrap bin)	600
	3,553
Total Phase 1 Footage (7.36 mi.)	38,859
PHASE 2	
Main	
119+81 (East Junction) to 194+01	7,420
257+79 to 263+97 (End)	618
	8,038
West	
0+00 to 75+06 (End)	7,506
North	
0+00 to 48+73	4,873
Tracks SA-SE	2,237
	7,110
Total Phase 2 Footage (4.29 mi.) 22,654	

The mileages indicated correspond to the surfacing footages, as shown in Table C-5.

Phase	Quantity (tons)	Mileage	$ Estimate
1	10,100	7.36	147,600
2	5,900	4.29	86,060
Total	16,000	11.65 mi	$233,700

Notes:

1. Unit Cost estimate of $20,060/mile based on:
   a. Ballast quantity of 0.2 cu yd per track ft (1,056 cu yd/mi.) @ $10.00/cu yd. delivered to site, or
   b. Unloading operation @ $9,500/mile.
2. Locations for ballast unloading are the same as for surfacing (Remedial Action 12).
3. 1 cubic yard of ballast weighs approximately 1.3 tons. 4) Ballast needed for rebuilding track in crossings is included in the estimate for rebuilding road crossings.
4. Estimate includes AREMA standard 15 percent allowance for ballast waste and loss.

C-6.2.12 Surface Track/Reshape Ballast Section.

The main surfacing and tamping operation includes:

- Lifting the track 3 in.
- Restoring proper track line and surface.
- Reshaping the ballast section.

The limits for this work are as shown in Table C-5.

During the final design process, check the sidings serving the loading docks and magazine standards to ensure that there is proper horizontal and vertical clearance between the track and the loading platform. Make any required corrections during track surfacing.

Phase	Mileage	$ Estimate
1	7.36	55,200
2	4.29	32,175
Total	11.65 mi	$87,375

Notes:

1. The Unit Cost estimate for surfacing is $10,560/Mile. Included in the cost is the following work:

   a. Raising the track 3 in.

   b. Plowing new ballast back into the track to fill in up to the tops of the ties.

   c. Reshaping the ballast section.

   d. Sweeping the track.

For Phase 1, estimate assumes no track raise through the track scale, and also assumes that track will be raised to level of existing crossings in the sidings along the East Line (Buildings A - F).

For Phase 2, provide a 12-in. shoulder in the track washout areas along the Main Line.

C-6.2.13 Herbicide Application.

Once the track work is complete, treat all track to prevent the growth of weeds in the ballast section.

While vegetation spraying at least once per year is recommended, this estimate is for one initial heavy application over a 16-ft wide path (8 ft from the center line of track on both sides).

Phase	Mileage	$ Estimate
1	10.7	3,200
2	8.5	2,600
Total	19.2 mi	$5,800

Note: Contract herbicide application is priced per day. As a rough estimate, a unit cost of $300/mi was used.

Phase 1 to include all Classification Yard tracks.

C-6.2.14 Quality Control Inspection.

Although listed last, quality control inspection is an essential element for a successful track rehabilitation. It is an effective means of assuring that all work reflects good workmanship and is performed according to the contract specifications.

Phase	$ Estimate
1	29,950
2	33,470
Total	$63,420

Note: Inspection cost estimate based on $35/Hour basic labor and overhead charge, or $280/Day, and $100/Day subsistence expenses. Total = $380/Day.

Allowance for travel to and from site of one round trip/week = $500.

Total Inspection Cost/Week = $2,400.

Phase 1 and 2 estimated to require 5 weeks each of on-site inspection.

C-7 CONCLUSIONS AND RECOMMENDATIONS.

Proper track restoration will involve remedial work that requires special attention. It is essential that this work be done by skilled workers, with knowledgeable and attentive supervision.

As indicated in the report, there are still some areas that need further examination before detailed contract specifications can be made, particularly in the improvement of drainage in areas where track washouts have occurred. Include these additional determinations as part of the final design process.

If the design work is to be contracted to an outside organization, it is recommended that a single design/inspection package be considered. Having the track work designed and inspected by the same organization has great potential for improved quality control and accountability throughout the project.

To further clarify the work plan and contract specifications, mark the work requirements (by type and location) in the field, whenever practical. This might include: marking with paint those switch ties that need replacement, setting flags or stakes to indicate the limits where extra shoulder ballast is required, painting a code at each road crossing to indicate which type of reconstruction is to be done, and noting any other indicators that help guide the field work.

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APPENDIX D GLOSSARY

ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AHJ	the Authority Having Jurisdiction
ASTM	American Society of Testing and Materials
AREMA	American Railway Engineering and Maintenance-of-Way Association
AWPA	American Wood Preservers Association
AFCEC	Air Force Civil Engineer Center
BIA	Bilateral Infrastructure Agreement
CAPY	capacity
CCR	criteria change request
CONUS	The Continental U.S.
CWR	continuous welded rail
DoD	Department of Defense
ESQD	Explosive Safety Quantity Distances
FEMA	Federal Emergency Management Agency
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
ITO	Installation Transportation Officer
MUTCD	Manual of Uniform Traffic Control
NAVFAC	Naval Facilities Engineering Systems Command
OTM	other track materials
OCONUS	Outside the Continental U.S.
POL	petroleum, oil and lubricants
Q-D	quantity-distance
RTCH	Rough Terrain Container Handler

SOFA	Status of Forces Agreements
TI	technical instructions
TM	technical manual
UFC	Unified Facilities Criteria
U.S.	United States
USACE	U.S. Army Corps of Engineers

APPENDIX E REFERENCES

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS

A Policy on Geometric Design of Highways and Streets, 2018, 7th Edition, Washington, DC

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION (AREMA)

Manual for Railway Engineering, Volumes 1 - 4, Published Annually, Washington, DC

Portfolio of Trackwork Plans, Published Annually, Washington, DC

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

Annual Book of ASTM Standards

AMERICAN WOOD PROTECTION ASSOCIATION

American Wood Protection Association Standards, Published Annually, Birmingham, Alabama

ASSOCIATION OF AMERICAN RAILROADS

Signal Manual of Recommended Practice, Washington, DC

DEPARTMENT OF TRANSPORTATION-FEDERAL HIGHWAY ADMINISTRATION

Manual on Uniform Traffic Control Devices for Streets and Highways

Railroad-Highway Guide Crossing Handbook

TEXTBOOKS

Hay, William W. 1982. *Railroad Engineering*. John Wiley & Sons, New York, NY

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

UFC 1-200-01, *DoD Building Code*

UFC 3-201-01, *Civil Engineering*

UFC 3-250-11, *Soil Stabilization and Modification for Pavements*

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*

UFC 4-860-03, *Railroad Track Maintenance and Safety Standards*

US ARMY CORPS OF ENGINEERS OMAHA DISTRICT

Standard Details for Chain-Link Security Fences and Farm Style Fences

Standard Details for Railroad Construction, Sheets C-5.1 – C-5.24