17.5 MISCELLANEOUS

17.5.1 Structural Design of Concrete Bridge Rails

Section 17.6 discusses the types of bridge rails used by the Department.

Concrete bridge railings will be built monolithically and continuous with no contraction joints. Full-depth open joints shall be provided at all expansion joints on structures, and these shall be the only locations for joints in concrete bridge rails.

Shear steel connecting any concrete barrier, curb, parapet, sidewalk, or median to the concrete decks should be determined assuming full composite action at the interface, according to the provisions of LRFD Article 5.8.4.

Superelevated sections can result in insufficient concrete cover for reinforcing bars; therefore, the designer should give special attention to barrier reinforcing steel placement for structures with superelevated sections.

17.5.2 Deck Drainage

See Chapter 18 for information on bridge deck drainage.

17.6 BRIDGE DECK APPURTENANCES

17.6.1 Bridge Rails

Reference: LRFD Article 13.7

17.6.1.1 Test Levels

Reference: LRFD Article 13.7.2

LRFD Article 13.7.2 identifies six test levels for bridge rails, which have been adopted from NCHRP 350 *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. Test Levels One, Two, and Six have no application in South Carolina. The following identifies the general test level application for TL-3, TL-4, and TL-5:

1. TL-3 (Test Level 3). Generally acceptable for a wide range of high-speed arterial highways with very low mixtures of heavy vehicles and with favorable site conditions. Performance crash testing is at 60 mph with a 1.55-kip passenger car and a 4.5-kip pickup truck.

2. TL-4 (Test Level 4). Generally acceptable for the majority of applications on high-speed highways, freeways, and expressways with a mixture of passenger cars, trucks, and other heavy vehicles. Performance crash testing is at 60 mph with a 1.55-kip passenger car and a 4.5-kip pickup truck plus an 18-kip single-unit truck at 50 mph.

3. TL-5 (Test Level 5). Generally acceptable for the same applications as TL-4 plus where large trucks make up a significant portion of the vehicular mix.

17.6.1.2 Bridge Rail Types/Usage

The following identifies typical SCDOT usage for bridge rails:

1. 32-in Concrete Bridge Barrier Parapet. SCDOT typically uses this bridge rail on all bridges that do not include sidewalks; however, see Item #4. The 32-in concrete bridge barrier parapet, which has the same face configuration as the typical SCDOT concrete median barrier, meets the performance criteria for a TL-4. SCDOT typically uses the Jersey shape for the 32-in rail instead of the other available concrete bridge rail shapes (e.g., F-shape, constant-slope shape, vertical wall). The SCDOT standard concrete bridge barrier parapet transition shall be used at all barrier ends where a thrie beam guardrail bridge connector is required. A separate bid item is required for the transition. The concrete bridge rail's advantages when compared to a metal beam rail include its superior performance when impacted by large vehicles, its relatively low maintenance costs, and its better compatibility with the bridge deck system (i.e., the concrete rail can be constructed integrally with the bridge deck). The concrete bridge rail's disadvantages include its higher dead weight.

2. 42-in Concrete Wall. SCDOT typically uses this rail where sidewalks are present on the bridge. The 42-in concrete wall is vertical, and its height conforms to the LRFD requirements for pedestrian rails; therefore, its use where sidewalks are present avoids the need to extend the height of a 32-in concrete bridge rail to meet the height requirements of a pedestrian rail. However, see Section 17.6.3 for warrants for bicycle rails. The 42-in concrete wall meets the TL-5 performance criteria, although SCDOT does not typically use this barrier for those highway facilities that may warrant consideration for the TL-5 rail. Figure 17.6-1 illustrates the transition that is required for the 42-in concrete wall at all rail ends where a thrie beam guardrail bridge connector is used. For concrete bridge rails with heights other than 42 in, the length of the transition shall be modified as necessary to maintain the 6:1 taper in Figure 17.6-1. A separate bid item is not required for this transition. The length of transition shall be included in the quantity for the concrete bridge rail.

3. Metal Beam Rail. SCDOT strongly discourages the use of any metal beam bridge rail system. Its use may only be considered where aesthetics or dead loads are very important. When compared to the concrete bridge rail, a metal beam rail's advantages include lower dead weight and providing a more open view of the surrounding scenery. The comparative disadvantages include a lesser ability to contain heavier vehicles, higher maintenance costs, and a more complex structural connection to the bridge deck system.

4. 32-in Concrete Wall. For bridges that meet all of the following conditions:

   - 60 ft or less in length;
   - straight wing walls (i.e., wing walls that are parallel to the centerline of bent); and
   - where sidewalks or bikeways are not provided,

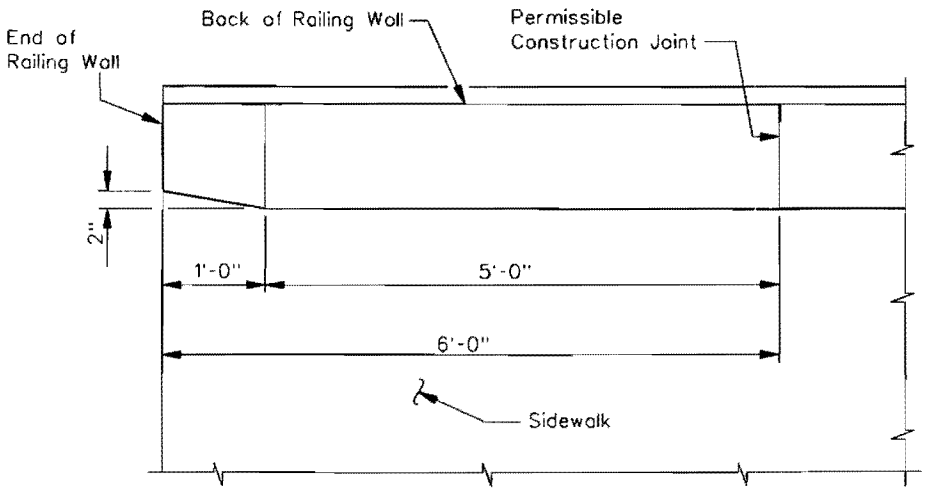
   a 32-in reinforced concrete wall with a vertical face shall be used. See Figure 17.6-2.

17.6.1.3 Guardrail-To-Bridge-Rail Transitions

The Road Design Section is responsible for designing and detailing the guardrail-to-bridge-rail transition for the approaching roadway. However, site conditions may present problems for the necessary transition. Therefore, the bridge designer should work with the Road Design Section to ensure compatibility between the guardrail-to-bridge-rail transition and the site.

17.6.1.4 Approach Slabs with Trend Guardrail

Where an approach has an adjoining Trend guardrail, the approach slab edge shall be terminated 4½ in inside the bridge gutter line. This avoids a conflict with the Trend's concrete pad footing. In addition, the designer shall eliminate the concrete curb from the approach slab edge where adjoining a Trend guardrail.



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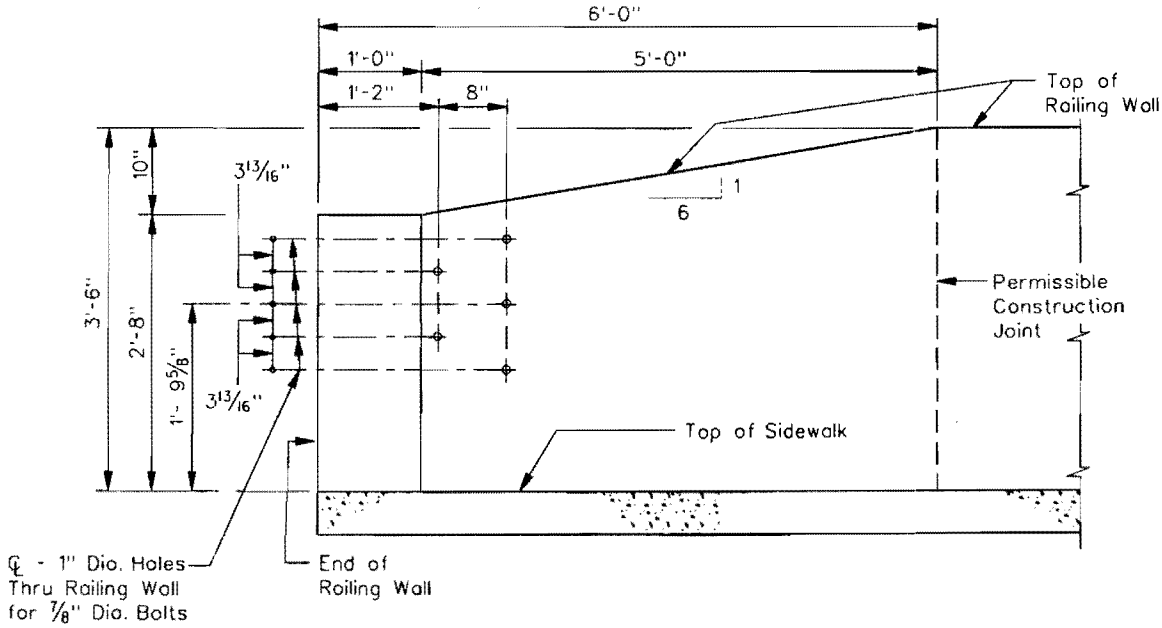
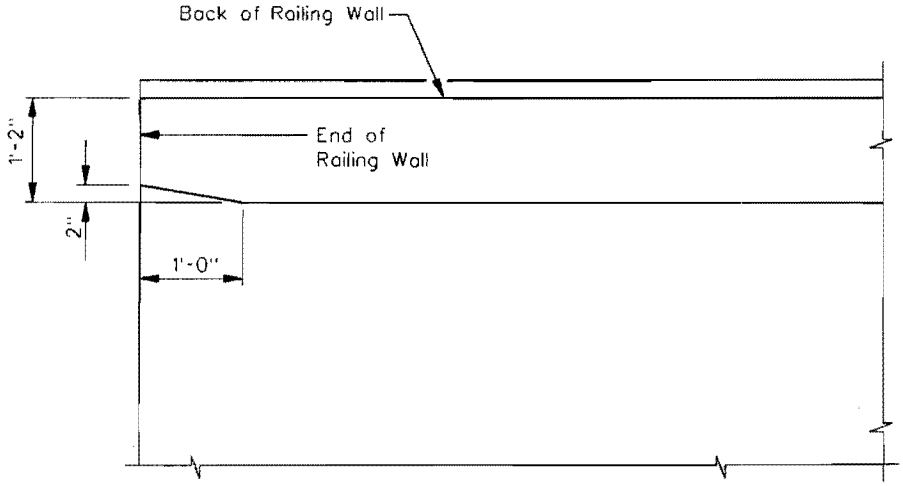


ELEVATION

END TRANSITION FOR 42-INCH CONCRETE WALL

Figure 17.6-1



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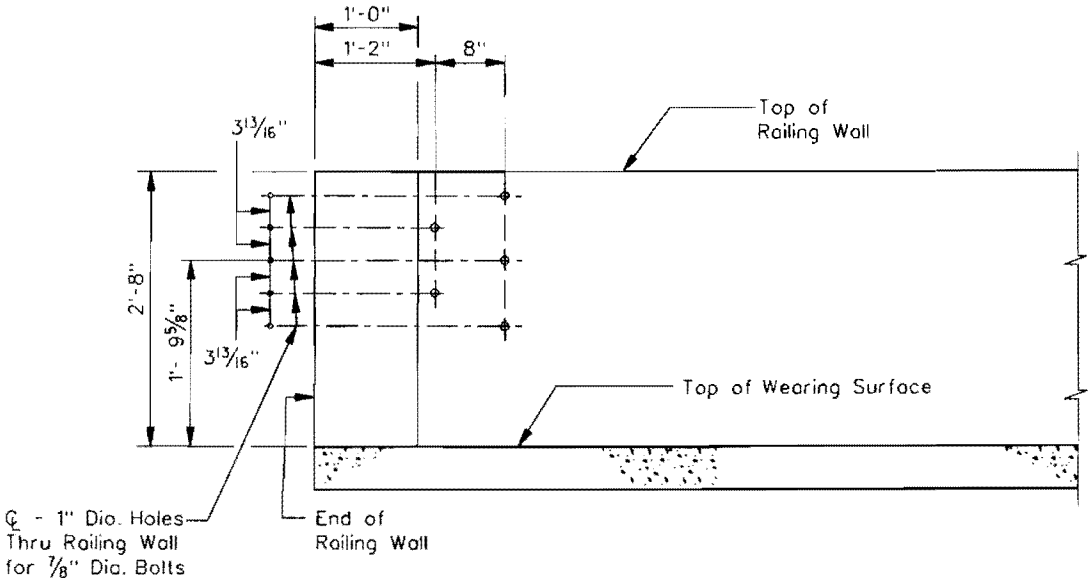

ELEVATION

32-INCH VERTICAL WALL

Figure 17.6-2

17.6.1.5 Bridge Rail/Sidewalk

Reference: LRFD Articles 13.4 and 13.7.1.1

Section 12.6 discusses warrants for a sidewalk on a bridge. At lower speeds, the sidewalk is separated from the adjacent roadway by a vertical curb, which is typically 6 in high. However, at higher speeds, the vertical curb will interfere with the proper vehicular/bridge rail interaction. See Figure 12.6-7. Therefore, the following will apply to the location of a bridge rail in combination with a sidewalk:

1. V ≤ 45 mph. The 42-in concrete wall is typically located on the outside edge of the sidewalk.

2. V ≥ 50 mph. Place the 32-in concrete bridge barrier parapet between pedestrians and traffic; i.e., between the roadway portion of the bridge deck and the sidewalk. The 32-in concrete barrier must have a metal hand rail on top of the barrier to reach the required 42-in height for a pedestrian rail. A 42-in pedestrian rail is then used at the outside edge of the sidewalk. For this arrangement, the roadway and sidewalk portions of the bridge deck are at the same elevation.

17.6.2 Pedestrian Rails

Reference: LRFD Article 13.8

Pedestrian rails are used on bridges with sidewalks where the roadway and sidewalk are separated by a barrier.

17.6.3 Bicycle Rails

Reference: LRFD Article 13.9

Section 12.6 discusses the conditions for which bicycle accommodation is required across a bridge. Where required, a bicycle rail that meets the geometric and loading requirements of LRFD Article 13.9 must be provided. The required height of the bicycle rail is 54 in. Therefore, where bicycle accommodation is required, rail height is treated as follows:

1. Bridge Without Sidewalk. Typical SCDOT practice is to use the 32-in concrete bridge barrier parapet and extend its height to 54 in with a metal rail that meets the LRFD bicycle rail requirements.

2. Bridge With Sidewalk. Where bicyclists are not legally allowed on sidewalks, the 42-in concrete wall (as discussed in Section 17.6.1) is typically used to satisfy the height requirements of a pedestrian rail. Where bicyclists are legally allowed on sidewalks, typical practice is to use a 30-in concrete wall and extend its height to 54 in with a metal rail that meets the LRFD bicycle rail requirements.

Bicycle paths are bikeways that are physically separated from motorized vehicular traffic by an open space or barrier and may be either within the highway right-of-way or within an independent right-of-way. Bridges that are part of a bicycle path may require a 54-in bicycle rail.

17.6.4 Fences

The need for protective fencing across bridges will be determined on a case-by-case basis. Typical applications are as follows:

- on an overpass near a school, playground, or other location where it is expected that the overpass will be frequently used by children not accompanied by adults;
- on all overpasses in urban areas that are used exclusively by pedestrians and not easily kept under surveillance by law enforcement personnel;
- on overpasses with walkways where experience on similar structures indicates a need for fences;
- on overpasses where private property that is subject to damage, such as buildings or power stations, is located beneath the structure; and
- on overpasses over railroads, if requested by the railroad company (see Chapter 22).

For the majority of projects, the use of a protective screen is not warranted, and the protective screen may be erected at a later time if site conditions change.

17.6.5 Utility Attachments

The Bridge Design Section will coordinate with the Utilities Office for any utility attachments proposed on the bridge.

Utility companies frequently request the approval from SCDOT to attach utility lines or pipes to bridges. The Bridge Design Section's concern is that the function of the bridge as part of a transportation corridor not be compromised; that the safety of the individuals using the bridge not be compromised; and that the Department's maintenance of the bridge not be unduly complicated. The Bridge Design Section also recognizes that existing transportation corridors offer logical routes for utilities and that, if the Department allows utility attachments to bridges, SCDOT can reduce costs to the Utilities and ultimately to the general public.

On new or replaced bridges, the bridge designer shall detail two 2-in diameter conduits in each concrete bridge rail for the future use of the Department or Utility Companies.

The Department has established guidelines for processing utility encroachment applications on new structures. These guidelines illustrate acceptable methods for attaching utility line(s) to Department-owned structures. The following applies to utility attachments:

1. Utility line(s) can not be attached to the outside edge of the bridge where the structure crosses another highway or where aesthetics are a concern. The attachment shall be between the exterior beam and the first interior beam.

2. Utility line(s) can not hang below the bottom of the beams or below the bottom of the deck on flat slab bridges.

3. Utility line(s) can not be attached to the bottom of concrete flat slabs.

4. No field welding is allowed on steel beams and no field drilling is allowed on concrete beams.

5. All attachments to concrete shall be made with inserts or epoxy-resin anchors. Attachment hardware shall be galvanized or stainless steel.

6. If SCDOT must increase the bridge capacity or extend elements such as bent caps to support a utility, the Utility must pay for the additional design and construction costs.

17.6.6 Sign Attachments

If the Traffic Engineering Division proposes to attach a sign to a bridge, the Traffic Engineering Division must coordinate with the Bridge Design Section. The Bridge Design Section will assess the structural impact on the bridge and, if the sign attachment is approved, the Bridge Design Section will design the attachment details. Signs can not decrease the vertical clearance.

17.6.7 Lighting/Traffic Signals

The Traffic Engineering Division determines the warrants for highway lighting and traffic signals, and the Traffic Engineering Division performs the design work to determine, for example, the spacing of the luminaries and the provision of electricity. Lighting will often be included on bridges that are located in urban areas; traffic signal warrants are determined on a case-by-case basis. Where attached to a bridge, the Bridge Design Section will design the structural support details for the luminaire and/or traffic signal attachments to the bridge.

Chapter 22

HIGHWAY BRIDGES OVER RAILROADS

SCDOT BRIDGE DESIGN MANUAL

April 2006

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CHAPTER 22

HIGHWAY BRIDGES OVER RAILROADS

22.1 PROCEDURES

These procedures apply to projects being designed in-house. For Consultant-designed projects, the Consultant will be responsible for coordination with all railroad companies that may be affected.

22.1.1 Utilities Office

The Utilities Office is responsible for coordinating with the railroad companies where SCDOT projects impact railroads. The Utilities Office's responsibilities include obtaining cost estimates for securing agreements with railroad companies for the relocation and adjustment of their facilities, as required for highway construction, and conducting direct negotiations with railroad companies, when necessary.

22.1.2 Project Development

Because of the unique nature of highway-railroad grade separations, special coordination must occur when a railroad alignment and a highway alignment intersect or when these alignments are in close proximity to each other. A conceptual layout is developed considering the minimum horizontal and vertical clearances in this Chapter. The Project Manager will submit the conceptual bridge plans to the Utilities Office. The Utilities Office will coordinate with representatives from the impacted railroad company and evaluate the following:

- construction of future tracks;
- off-track maintenance roadways;
- drainage requirements, from both the railroad's perspective and SCDOT's perspective; and
- bent locations.

The Utilities Office will advise the Project Manager if the conceptual plans are acceptable or if revisions are needed to the conceptual layout. Preliminary bridge and road plans will be developed and then forwarded to the Utilities Office through the Project Manager. In addition, the Project Manager shall also provide an explanation of the proposed project. The Utilities Office will forward the plans to the railroad company for review and approval.

See Chapter 2 for a discussion on how the coordination with railroad companies is incorporated into the project development process for a bridge project.

22.2 DESIGN CRITERIA

22.2.1 General

Highway bridges constructed over or near railroads must be designed to be consistent with the geometric requirements of railroads. This includes criteria for lateral clearances, vertical clearances, and the width of the railroad roadbed section. These criteria are based on:

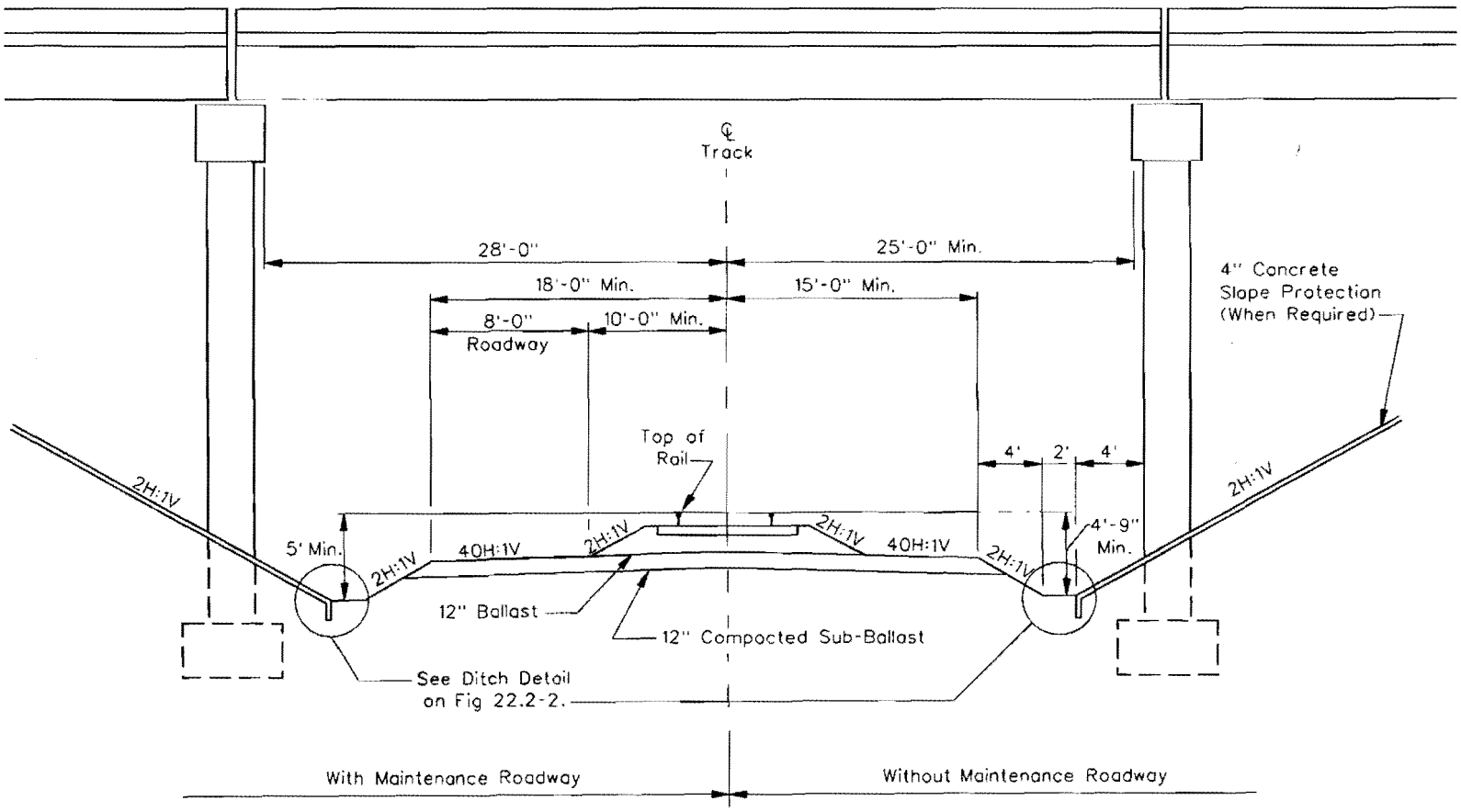
- the Federal Highway Administration participation limits for railroad geometrics;
- the requirements of the State of South Carolina;
- the specifications of the American Railroad Engineering and Maintenance-of-Way Association (AREMA); and
- the criteria established by individual railroad companies (i.e., CSX Transportation and Norfolk Southern Corporation).

22.2.2 Basic Geometric Configuration

The basic geometric configuration of the railroad cross section passing under a highway bridge is primarily based on the following factors:

- number and type of tracks,
- drainage treatments,
- maintenance roadway,
- specific requirements of individual railroad companies, and
- end slope. (Note: This will be 2H:1V maximum unless it is specifically engineered for stability at a steeper slope and slope protection is provided).

Figures 22.2-1 and 22.2-2 present the basic railroad cross sections based on these variables. Sections 22.2.3 and 22.2.4 present additional information that must be considered. Meeting the clearance requirements in Figures 22.2-1 and 22.2-2 typically determines the bridge length.

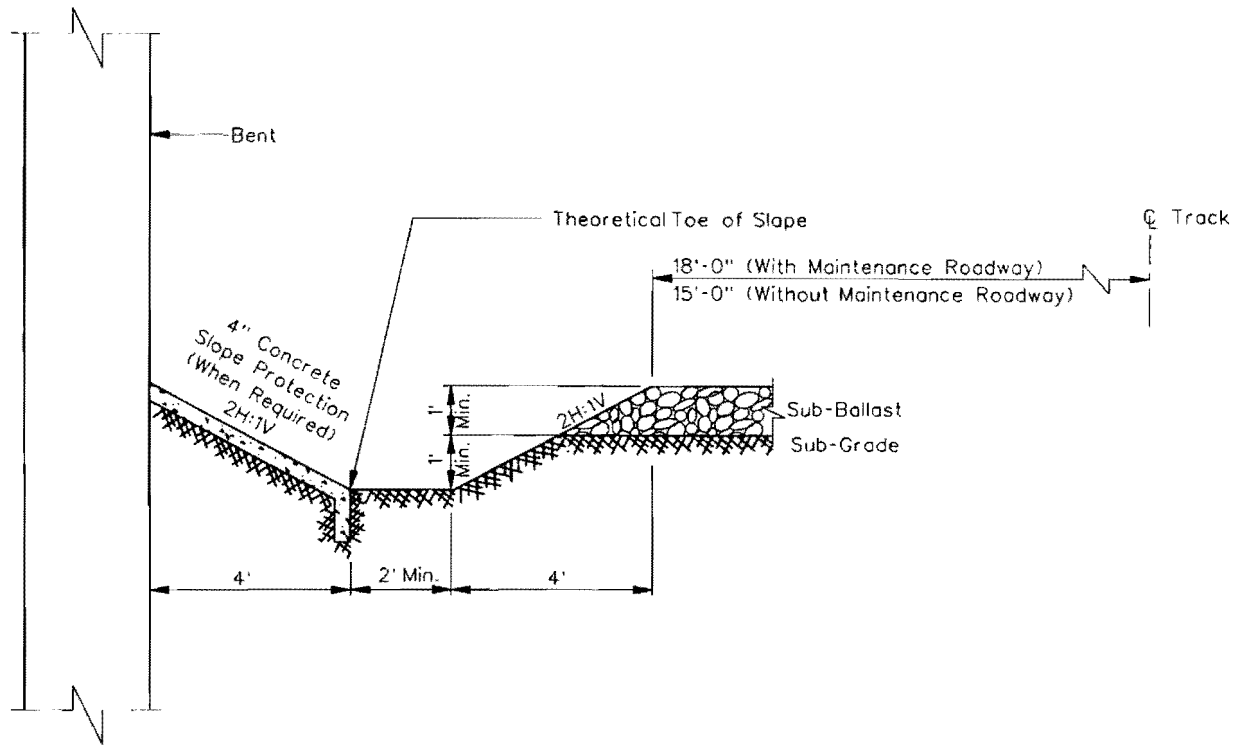


Notes:

1. *Horizontal dimensions shown are perpendicular to centerline of track.*
2. *Horizontal dimensions shown are the minimum distances to construct a standard railroad roadbed section. Actual required horizontal clearances may need to be increased due to the existing roadbed section and alignment, location of parallel ditches, and hydrologic conditions.*
3. *See Figure 22.2-3 for vertical clearances.*

RAILROAD CLEARANCES

Figure 22.2-1



Notes:

1. *Theoretical toe of slope is based on the standard railroad roadbed section. Actual toe of slope may vary due to existing ground line.*
2. *The ditch section shown is the minimum acceptable section.*
3. *The ditch section must be increased as required by local conditions, location of parallel ditches, and hydrologic condition.*

RAILROAD CLEARANCES
(Ditch Detail)

Figure 22.2-2

22.2.3 SCDOT/AREMA Recommendations

The American Railroad Engineering and Maintenance-of-Way Association (AREMA) publishes the *AREMA Manual*, which provides design standards for railroads. In addition to the *AREMA Manual,* SCDOT, in conjunction with CSX Transportation and Norfolk Southern Corporation, has developed specifications and design recommendations that will apply to the railroad cross section under a highway bridge.

22.2.3.1 Regulatory Template for Tangent Sections of Track

Figure 22.2-3 is the railroad template for permanent construction.

22.2.3.2 Clearances Under Bridges

The clearances shown in Figures 22.2-1 and 22.2-2 are for tangent track. In addition, consider the following:

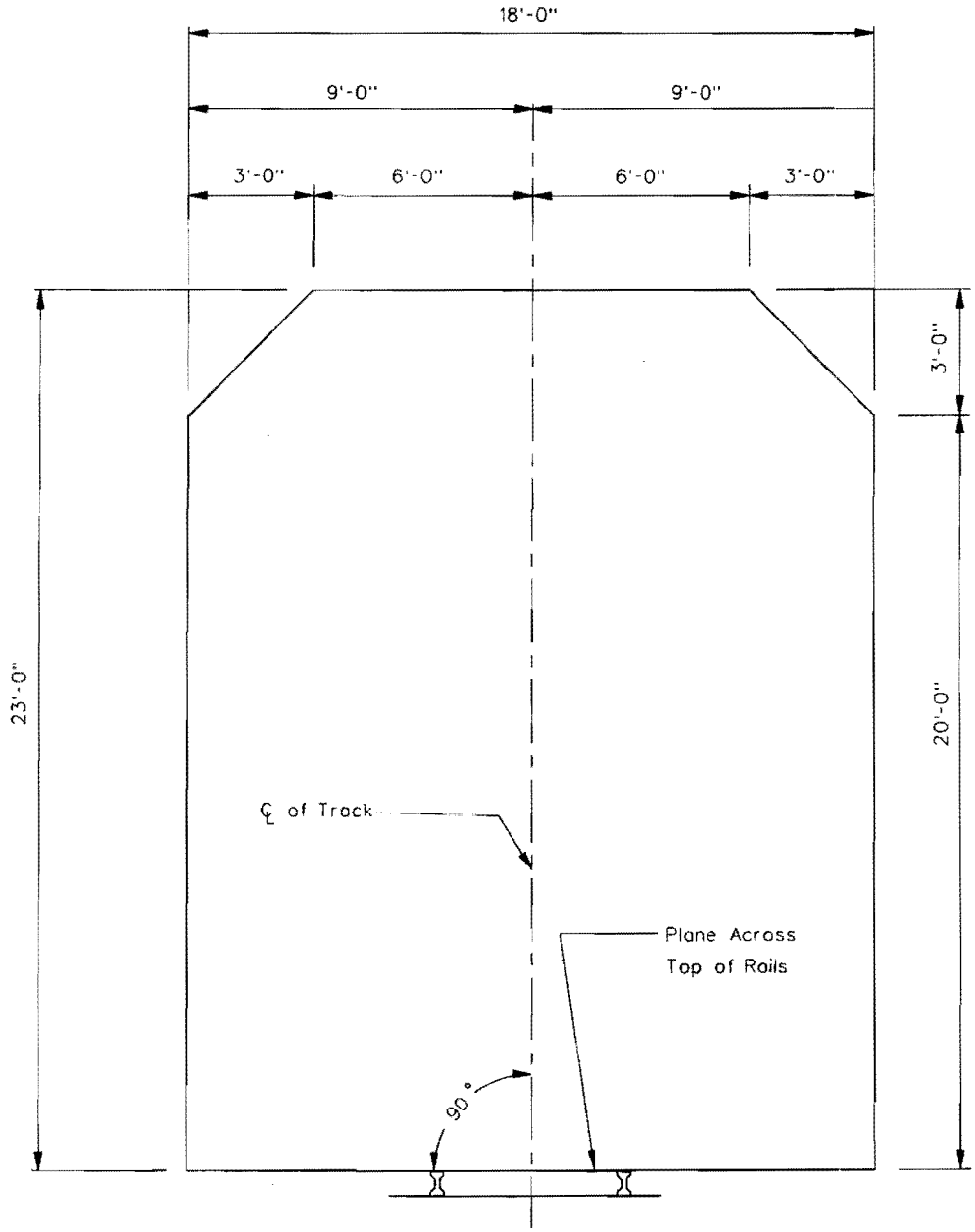
1. Horizontal Clearances (Tangent Track). End bents and/or interior bents for overhead bridge structures shall be located to clear the ditches of a typical track roadbed section and, where possible, be set with a minimum of 25.0 ft from the face of bent to the centerline of track. Edges of the footing should not be closer than 15.0 ft from the centerline of the track.

2. Horizontal Clearances (Curved Track). On curved track, the lateral clearances on each side of the track centerline shall be increased 1.5 in per degree of curvature on the railroad alignment. When the fixed obstruction is adjacent to the tangent track but the track is curved within 80 ft of the obstruction, the lateral clearances on each side of track centerline shall be increased as shown in Figure 22.2-4.

   On superelevated track, the track centerline remains perpendicular to a plane across the top of rails. Where the track is superelevated, clearances on the inside of the curve shall be increased by 3½ in for each inch of elevation differential between the inside and outside edges of the superelevated section.

3. Vertical Clearances. Vertical clearances shall be set between a minimum of 23.0 ft and a maximum of 23.4 ft from the top of rail to the bottom of the superstructure. If the minimum finished grade elevation is not controlled by the vertical clearance, the 23.4 ft maximum does not apply.

4. Temporary Clearances. Temporary horizontal construction clearances shall be noted on the plans as a minimum of 13.0 ft for tangent tracks and 14.0 ft for curved tracks measured from the centerline of track. Temporary vertical construction clearance shall be noted as 22.0 ft above the top of high rail. The railroad company may request increased temporary clearances after review of the preliminary plans.



REGULATORY TEMPLATE FOR TANGENT TRACK
(Clearance Box)

Figure 22.2-3

Distance from Obstruction to Curved Track (ft)	Increase Per Degree of Curvature (in)
20	1½
40	1⅛
60	¾
80	⅜

Note: To convert radius of curve (R, in ft) to degree of curvature (D, based on the chord definition), $D = 2(\sin^{-1}(50/R))$.

LATERAL CLEARANCE INCREASE
(For Tracks on Horizontal Curves)

Figure 22.2-4

22.2.3.3 Track Center Distances

The minimum distance between track centers is 15.0 ft. Individual railroad companies may have different requirements. These requirements, and any plans the railroad companies may have for future additional tracks, must be determined early in the project.

22.2.3.4 Bridge Length

The length of the bridge shall be established by locating the toes of the end fill slopes to accommodate the standard railroad road bed profile with open ditches as shown in Figures 22.2-1 and 22.2-2. End fills shall be sloped at 2H:1V taken perpendicular to the tracks. Slopes flatter than 2H:1V may be used when required by a geotechnical analysis. Piping of railroad ditches shall not be allowed.

The Project Manager should note that the above method of establishing the bridge length conflicts with the current FHWA criteria, which allows a 20-ft maximum distance from the centerline of track to the face of the fill slope. Therefore, it will be necessary for the Department to request FHWA to grant an exception on an individual project basis.

22.2.3.5 Bent Protection

To limit damage by the redirection and deflection of railroad equipment, bents supporting bridges over railways and with a clear distance of less than 25.0 ft from the centerline of a railroad track shall be of heavy construction (defined below) or shall be protected by a reinforced concrete crash wall. The following will apply:

1. Single-Column Bents. Crashwalls for single-column bents shall be a minimum of 2.5 ft thick and shall extend a minimum of 10.0 ft above the top of high rail. The wall shall extend a minimum of 6.0 ft beyond the column on each side in the direction parallel to the track.

2. Multiple-Column Bents. The columns shall be connected with a wall of the same thickness as the columns or 2.5 ft, whichever is greater. The wall shall extend a minimum of 2.5 ft beyond the end of outside columns in a direction parallel to the track and shall extend at least 4 ft below the lowest surrounding grade.

3. Reinforcing Steel. Reinforcing steel to adequately anchor the crashwalls to the column and footing shall be provided.

4. Heavy Construction. For bents of heavy construction, crashwalls may be omitted. Heavy construction is considered as solid bents with a minimum thickness of 2.5 ft and a length of 20.0 ft; single-column bents of a minimum of 4.0 ft by 12.5 ft dimensions; or any other solid bent sections with equivalent cross sections and a minimum of 2.5 ft thickness.

22.2.3.6 Side Slopes

Concrete slope protection pavement should be provided where practical. Generally, concrete slope protection will not be provided where the tracks are located in a cut section having steep slopes. When concrete slope protection is not provided, consider providing a low retaining wall attached to the bents adjacent to the track to prevent the fill from sloughing into the railroad ditches.

22.2.3.7 Bridge Widenings

Existing horizontal and vertical clearances should be maintained for widening projects. If the existing vertical clearance is greater than 23 ft, it may be reduced to a minimum of 23 ft. Clearances for reconstruction work or for alteration of existing tracks are dependent on existing physical conditions and, where reasonably practical, should be improved to meet the requirements for new construction.

22.2.4 Railroad Company Design Criteria

Each railroad company operating within the State of South Carolina requests or requires that SCDOT comply with its design criteria for highway bridges over railroads. These may apply to restrictions during construction, fencing, drainage, erosion control, etc. The Project Manager must ensure that the Department coordinates early with the railroad companies, through the Utilities Office, to identify these site-specific design criteria.

22.2.5 FHWA Participation

The Appendix to Subpart B of 23 CFR 646 presents the limits of FHWA participation for the costs of highway bridges over railroads. For convenience, Figure 22.2-5 reproduces those portions of the FHWA regulations that are applicable in South Carolina. The Appendix to Subpart B of 23 CFR 646 implements provisions of 23 CFR 646.212(a)(3). Note that SCDOT practices may differ from the criteria in the FHWA regulations.

22.2.6 Fencing

A protective fence will be provided if requested by the railroad company.

22.2.7 Construction Requirements

For information on shoring for construction excavations, demolition of existing structures, and erection procedures, see the *SCDOT Standard Specifications* and Supplemental Specifications.

Construction casing shall be specified for drilled shafts that are located within 30 ft of the centerline of an existing railroad track. For drilled shaft locations greater than 30 ft from the centerline of a track, consideration shall be given to requiring construction casing.

22.2.8 Control of Drainage from Highway Bridge Deck

Deck drains shall not be allowed to discharge onto railroad right-of-way. Chapter 18 discusses bridge deck drainage. When drains are required within the railroad right-of-way, a closed drainage system shall be used, and the drainage shall be directed away from the railroad right-of-way.

Lateral Geometrics

A cross section with a horizontal distance of 6.1 meters, measured at right angles from the centerline of track at the top of rails, to the face of the embankment slope, may be approved. The 6.1-meters distance may be increased at individual structure locations as appropriate to provide for drainage if justified by a hydraulic analysis or to allow adequate room to accommodate special conditions, such as where heavy and drifting snow is a problem. The railroad must demonstrate that this is its normal practice to address these special conditions in the manner proposed. Additionally, this distance may also be increased up to 2.5 meters as may be necessary for off-track maintenance equipment, provided adequate horizontal clearance is not available in adjacent spans and where justified by the presence of an existing maintenance road or by evidence of future need for such equipment. All piers should be placed at least 2.8 meters horizontally from the centerline of the track and preferably beyond the drainage ditch. For multiple track facilities, all dimensions apply to the centerline of the outside track.

Any increase above the 6.1-meters horizontal clearance distance must be required by specific site conditions and be justified by the railroad to the satisfaction of the State highway agency (SHA) and the FHWA.

Vertical Clearance

A vertical clearance of 7.1 meters above the top of rails, which includes an allowance for future ballasting of the railroad tracks, may be approved. Vertical clearance greater than 7.1 meters may be approved when the State regulatory agency having jurisdiction over such matters requires a vertical clearance in excess of 7.1 meters or on a site by site basis where justified by the railroad to the satisfaction of the SHA and the FHWA. A railroad's justification for increased vertical clearance should be based on an analysis of engineering, operational and/or economic conditions at a specific structure location.

EXCERPT FROM
APPENDIX TO SUBPART B OF PART 646—HORIZONTAL AND VERTICAL CLEARANCE PROVISIONS FOR OVERPASS AND UNDERPASS STRUCTURES

Figure 22.2-5