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Division of Highways
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Governor

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Secretary of Transportation/
Commissioner of Highways

March 2, 2016

MEMORANDUM

TO: ALL HOLDERS OF BRIDGE DESIGN MANUAL

FROM: R. J. Scites, P. E.
Director
Engineering Division

SUBJECT: Bridge Design Manual Revisions Chapter 2

For your use is the Engineering Division's Chapter 2 revisions for the Bridge Design Manual. These revised sheets replace all previous copies and contain the following revisions to Chapter 2 as noted below:

Section 2.1.6 – Highway Drainage, and Hydrology and Hydraulics.
This section was completely re-written with the section on Highway Drainage being eliminated.

Section 2.2.2.1 – Stream Crossing.
This section was completely re-written.

Section 2.3 – Geotechnical Investigations.
All headings under this section were revised as shown on attachment.

Section 2.4.3.6 – Geosynthetic Reinforced Soil – Integrated Bridge System Abutment (GRS-IBS).
This section was added.

Old Section 2.5.2 – Slope Stability.
This section was moved to Section 2.3.

Section 2.7.1 – Bridge Inspection.
This section was completely re-written.

Section 2.11.4.1 – Geotechnical Report.
This section was revised as shown on attachment.

The Bridge Design Manual and Interims are available on the West Virginia Division of Highways website at http://www.transportation.wv.gov/highways/engineering/pages/publications.aspx.

Should you require any additional information, please contact Todd West of this office by e-mail at todd.g.west@wv.gov.

RJS:Lkc

cc: DDC(TGW, MDL), DD (via email), DD(MF)

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SECTION 2 - BRIDGE DEVELOPMENT PROCESS

2.1 PROJECT DESIGN CRITERIA

All designs shall be in accordance with the latest edition of the *AASHTO LRFD Bridge Design Specifications* (Governing Specifications), including all interim specifications and the *West Virginia Division of Highways Standard Specifications, Road and Bridges* (Standard Specifications) including the latest supplemental specifications.

See Section 600 of the Design Directives (DD) for information that is applicable to the roadway design criteria associated with bridge planning. Reference is also made to DD-202, which contains the Bridge Submission Checklists for each phase of the project.

When a project consists of total Bridge Replacement or a Bridge Rehabilitation Project is converted to a Bridge Replacement, the Project Manager shall verify that the Bridge Sufficiency Rating is less than 50 if Federal Funding is being utilized.

2.1.1 Typical Deck Transverse Section

The typical deck transverse section shall be determined by the Project Manager (see DD-601).

Generally, the bridge width shall not be less than that of the approach roadway section and barriers shall be provided in accordance with the Governing Specifications.

2.1.2 Environmental Documentation

The WVDOH and/or Consulting Engineer will perform environmental evaluations. These documents will be supplied to the Project Manager for use in the design. Design Directives 201 and 206 discuss the environmental process and the necessary documentation.

Under most circumstances, bridge rehabilitations, reconstruction, and replacement projects will require a Class II (categorical exclusion) environmental action as defined in 23 CFR Section 711.117 (Code of Federal Regulations, U. S. Congress). Those structures requiring a Class I or Class III (Environmental Impact Statement or Environmental Assessment, respectively) environmental action are generally on a new alignment and will be part of a larger corridor study.

When requested by the Division of Highways, representatives from the WVDOH and/or the Consulting Engineer shall attend public information meetings to answer questions and provide information about the environmental study.

2.1.3 Right-of-Way

Right-of-way requirements shall be coordinated with the Right-of-Way Division of the Division of Highways (see DD-301).

2.1.4 Line and Grade Geometrics

The WVDOH will determine the line and grade on a project. If a Consultant is designing the project, then the line and grade will be determined by the Consultant, pending approval from the Project Manager. See DD-601 through 620.

2.1.5 Existing Project Related Information

Early in the project, the Bridge Designer should gather as much existing information about the project as possible. This information could prove to be extremely useful during the planning phase of the project. Available information could consist of inspection reports, bridge replacement studies, as-built plans on the existing bridge and roadway, among other items.

2.1.6 Highway Drainage, and Hydrology and Hydraulics

The WVDOH has developed a comprehensive Drainage Manual that shall be utilized in establishing design frequencies for Highway Drainage, and Hydrology and Hydraulics on new and replacement structures. See also Design Directives Section 501 and Governing Specifications Section 2.6.

A scour analysis shall be performed on all waterway or stream/river crossings and a DS-34 Form submitted (see Appendix C).

2.2 BRIDGE LAYOUT CRITERIA

2.2.1 Geometric Guidelines

The following are guidelines in the geometric layout of new or replacement structures:

- The desirable berm width in front of an abutment shall be as follows (see Figure 2.2.1A):
  - A minimum berm width of 3 FT shall be used under dry conditions.

    - For wet conditions, a berm width of 5 FT is preferred.
    - When very steep terrain is encountered, a berm width of 10 FT is desirable to facilitate safe construction practices.
- The berm should be at an elevation below the bridge seat that will allow access to the bridge seat for future maintenance (see Figure 2.2.1B).
    - A minimum 1.5 FT clearance between the berm and superstructure is required except that a minimum of 3.0 FT clearance between the bottom of the deck slab or the bottom of adjacent box beams and berm is required, whichever is greater. However, if the berm width is greater than 10 FT a minimum 3 FT clearance between the berm and superstructure should be used to provide clearance for ventilation and access.
    - Where conditions warrant (e.g., steep terrain or where additional construction clearance is required) a 3 FT minimum clearance is preferred.
- The maximum desirable skew is 30°; however, elimination of skew is preferable.
- The maximum skew for the ends of box beams is 30°. When the bridge is skewed greater than 30°, additional bridge seat width may be required along with a stepped backwall to compensate for the difference in skew angles.
- Substructure units that are either parallel to one another or radial to the roadway curvature are desirable. The number of substructure units is determined by cost comparisons of various span arrangements and the topography of the site.
- All horizontal and vertical clearances for roadways, railroads, navigable waterways or any adjacent features, that require a clear zone, shall be maintained. If they cannot be maintained, appropriate measures shall be taken to protect the public and the structure.
- The Bridge Designer shall consider the location of environmental features during the bridge layout phase.
- The maximum side slope of embankments is generally 2:1. Flatter slopes may be warranted by the existing topography, aesthetics, or slope stability concerns. However, steeper slopes up to 1 ½:1 may be utilized if soil/rock conditions permit and a geotechnical stability analysis is performed resulting in a minimum factor of safety of 1.5 under the substructure.

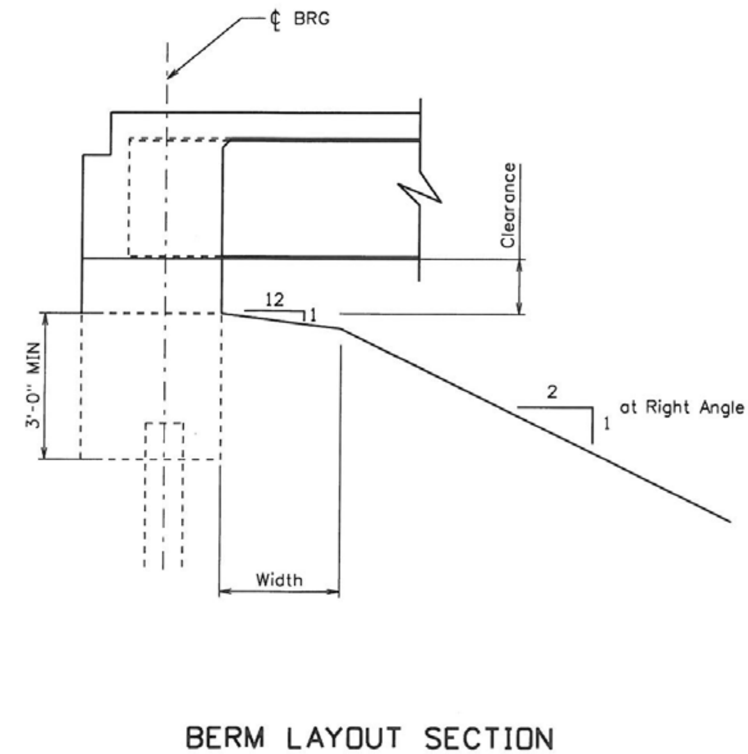
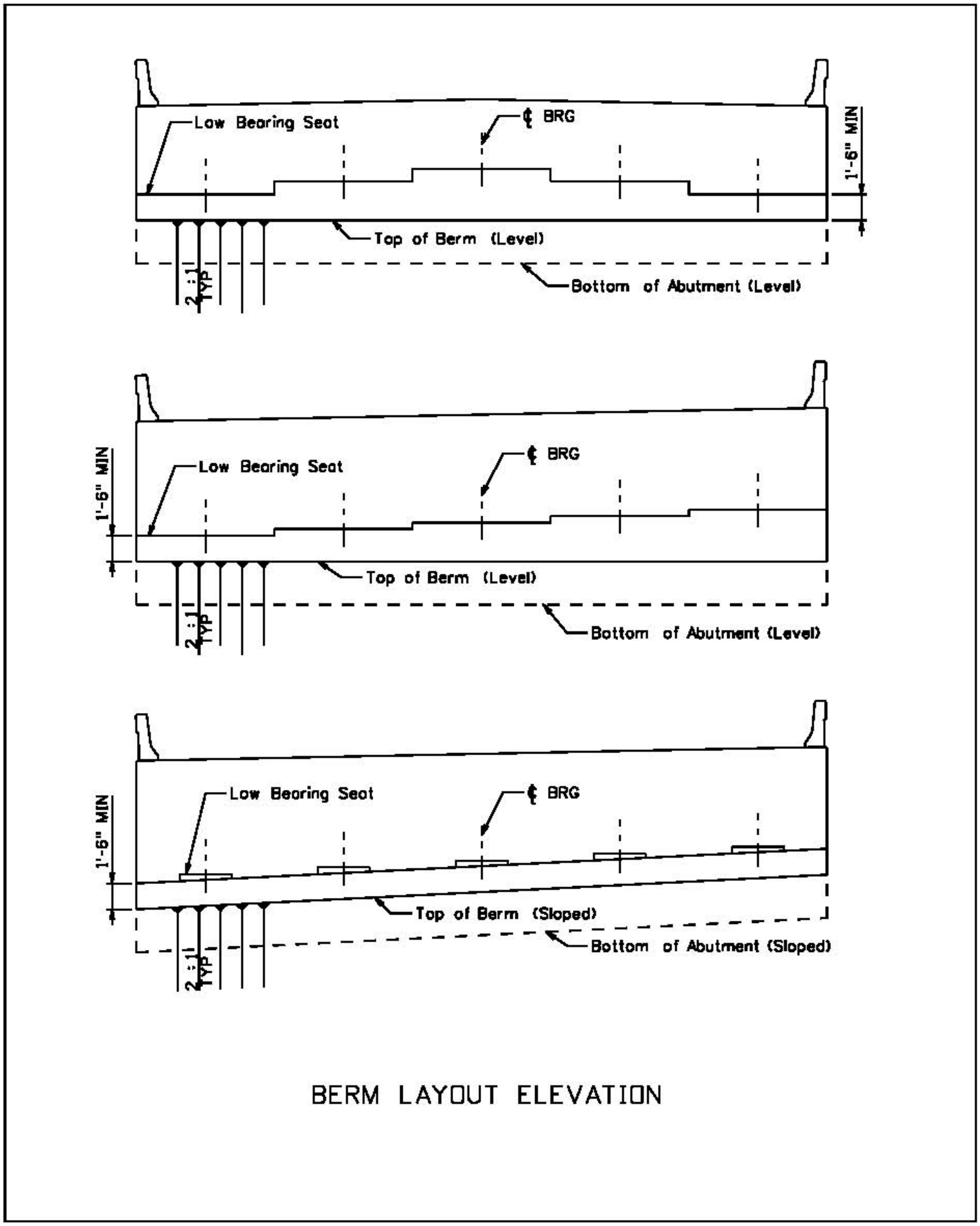

℄ BRG
Clearance
12
1
3'-0" MIN
2
1
at Right Angle
Width
BERM LAYOUT SECTION

Figure 2.2.1A



Low Bearing Seat
℄ BRG
1'-6" MIN
Top of Berm (Level)
2 : 1
TYP
Bottom of Abutment (Level)
Low Bearing Seat
℄ BRG
1'-6" MIN
Top of Berm (Level)
2 : 1
TYP
Bottom of Abutment (Level)
Low Bearing Seat
℄ BRG
1'-6" MIN
Top of Berm (Sloped)
2 : 1
TYP
Bottom of Abutment (Sloped)
BERM LAYOUT ELEVATION

Figure 2.2.1B

2.2.2 Bridge Length

The length of the bridge is determined by the attributes of the features that they cross, such as streams, highways, railroads, and cultural and natural resources.

2.2.2.1 Stream Crossings

Stream and floodplain crossings shall be designed to not make flooding or stream instability more severe. Refer to the WVDOH Drainage Manual for further guidance.

Freeboard, the clear distance above the design discharge elevation and the lowest portion of the superstructure, shall be 2 FT with assurance that the bridge bearings are above the design discharge elevation unless otherwise approved by the Director of Engineering.

The geometric design of the bridge and approach roadways may be an iterative process requiring the cooperation of the structures, roadway, hydraulic and geotechnical engineers.

The toe of the embankment shall not encroach into the stream channel.

The Designer should avoid a span arrangement that places a pier in or near the center of the stream. It is preferable for pier columns to be located outside the normal flow.

2.2.2.2 Highway Crossings

Bridge layouts for highway crossings are usually controlled by the cross section of the roadway below. Minimum vertical underclearances, horizontal safety clearances and adequate sight distances will frequently control not only the overall length of the bridge, but the span arrangement as well.

Relatively extreme gradients at either roadway grade require careful consideration of the vertical clearances. The point of minimum underclearance can be beneath any of the superstructure members at any point in the traveled way below. The superelevation rates for both alignments must be evaluated throughout the layout process. The Designer should consider the effects of future widening and the final grade shall provide the minimum vertical clearance.

When possible, obstructions (abutments, piers, etc.) should be placed outside of the clear zone. If an obstruction is within the clear zone, appropriate safety measures shall be incorporated, such as (but not limited to), guardrails, crashwalls, etc.

Table 2.2.2.2 shows horizontal and vertical clearances for highway crossings. For additional information, see DD-601.

Horizontal and Vertical Clearances for Highway Crossings		
Classification*	**Horizontal Clearance to Obstructions**	**Minimum Vertical Clearance**
Local Roads	10 FT from edge of traveled way.	14.5 FT over the entire roadway. This value includes a 6 IN future resurfacing allowance for new structures. **
Rural Collectors	Design speeds of 40 MPH and below - 10 FT from edge of pavement. Design speeds of 50 MPH and above - see the current edition of the AASHTO Roadside Design Guide.	14.5 FT over the entire roadway. This value includes a 6 IN future resurfacing allowance for new structures. **
Two-Lane Arterial	See the current edition of the AASHTO Roadside Design Guide	16.5 FT over the entire roadway and usable shoulder. This value includes a 6 IN future resurfacing allowance for new structures.
Divided Arterial	See the current edition of the AASHTO Roadside Design Guide.	16.5 FT over the entire roadway and usable shoulder. This value includes a 6 IN future resurfacing allowance for new structures.
Freeway	See the current edition of the AASHTO Roadside Design Guide.	16.5 FT over the entire roadway and usable shoulder. This value includes a 6 IN future resurfacing allowance for new structures. A minimum of 17.5 FT should be provided to pedestrian overpasses, sign trusses, and from the bridge deck to cross bracing on through trusses.

* The AASHTO functional classification system is to be used as a design type of highway for design purposes.
** Both Local Roads and Rural Collectors shall have a minimum vertical clearance of 16.5 FT when passing under an Interstate Route adjacent to the Interstate Interchange.

Table 2.2.2.2

2.2.2.3 Railroad Crossings

The two principal railroads currently operating in West Virginia are the Norfolk Southern Corporation (NS) and CSX Transportation, Inc. The proposed bridge length is determined from the embankment slopes and berm requirements similar to those for highway crossings. See Section 2.10 for clearance and additional railroad requirements.

2.2.2.4 Cultural and Natural Resources Crossings

The Designer should avoid any cultural and/or natural resources in the project area. The Designer must receive permission from the Director of Engineering Division when these areas cannot be avoided, prior to the advancement of the bridge layout.

2.3 GEOTECHNICAL INVESTIGATIONS

2.3.1 Introduction

The purpose of this information is to provide Design Engineers a guide to the proper procedures in the performance of geotechnical investigations. Specifically, this section is intended to define the procedures that may be involved in performing a subsurface investigation and the various geotechnical aspects of the design and construction of bridges and approach embankments. For the purpose of preliminary foundation design, existing geotechnical data or presumptive values found in the Governing Specifications may be used at the service limit state. All new or modified substructures shall have borings drilled and the foundation soils and rock shall be evaluated. All foundations, including pile foundations, must be designed in accordance with the Governing Specifications.

Each project presents unique considerations and requires engineering judgment based on a thorough knowledge of the individual situation. This section is not intended to serve as the geotechnical scope of services for individual projects. The scope of services dictates the specific practices, which are to be used on a particular project. Additionally, the scope defines the required interaction between the Design Engineer and those performing the geotechnical work. For In-House designed bridges, and for District designed bridges if needed, the bridge engineer shall determine the scope of the investigation with the Geotechnical Unit.

Details of coring requirements shall be contained in the Core Boring Contract Documents in the Span Arrangement Report. Core Boring Contract Documents are available from the Engineering Division and the WVDOH Web Site. Determination of soil and rock properties shall be in accordance with the Governing Specifications.

2.3.2 Structure Boring Requirements

The purpose of structure borings is to provide sufficient information about the subsurface materials to permit proper design and construction of the structure foundations. All structure borings shall include Standard Penetration Testing (SPT) at 5.0 FT intervals unless other sampling methods and/or in-situ testing are being performed. It is the

Engineer's responsibility to assure that appropriate explorations are carried out for each specific project.

A Geotechnical Inspector shall, as a minimum, witness at least one boring drilled to completion on each bridge project. Color photographs are to be taken for each core box showing the boring number, depths, recovery and Rock Quality Designation (RQD). Refer to the Design Directive DD-409 for the specific duties, qualifications, and definitions concerning Geotechnical Inspectors

2.3.2.1 Bridge Substructures

In most cases, two borings shall be obtained at each substructure unit. However, one boring may be adequate for smaller structures, with the approval of the Bridge Project Manager. The hole pattern should be staggered so that borings occur at the opposite ends of adjacent piers. Pier foundations or abutments may require at least two borings, preferably at the extremities of the proposed substructure. For structure widening, the total number of borings may be reduced depending on the information available for the existing structure. Additional borings to define general site conditions may be needed. General site conditions will include construction and post construction effects on: slope stability of stream banks, adjacent natural hillsides, adjacent cut slopes, approach embankments, erosion and scour potential, settlement of approach fill, mine voids and any other bridge related considerations requiring subsurface information. Unanticipated findings may require supplemental borings.

If pier locations are unknown, their approximate locations may be deduced based on experience and a preliminary design concept for the structure. Generally, place borings at no more than 100 FT intervals along the alignment if substructure locations cannot be deduced. Additionally, for projects with a pier in water, at least one boring should be located in the water when practical, depending on the width of the crossing. All bore holes shall be backfill in accordance with Section 19 of 47 CSR 60 Legislative Rules.

Continue the borings until all unsuitable foundation materials have been penetrated. For pile foundations core a minimum of 10.0 FT of rock. For spread foundations drill two times the estimated breadth of the foundation or a minimum of 10.0 FT into rock at the discretion of the Geotechnical Engineer. For drilled caissons core a minimum of three times the estimated shaft diameter into rock. If shaft locations are known, drill one boring at each shaft location. Scour, soft embankment foundation soils, and lateral squeeze must be taken into account when planning borings.

When using the Standard Penetration Test, split-spoon samples shall be obtained per AASHTO T206 Specifications.

When cohesive soils are encountered, undisturbed samples shall be obtained when N-Values of 4 or less are obtained. The N-Value is the sum of the last two consecutive blow counts when performing Standard Penetration Testing. Undisturbed samples shall be obtained from more than one boring where possible.

When rock is encountered, successive core runs shall be made with the objective of obtaining the best possible core recovery. Coring shall be initiated at N-Values of 50/6 IN but no deeper than 50/3 IN.

Corrosion tests are required on all new bridge projects where acidic soil or acid mine drainage is suspected.
When drilling for a bridge over a stream, bag samples of streambed materials shall be obtained for determination of the grain size distribution needed for scour analysis (refer to DD-409).

For projects where the potential for large ship impacts exists, or other critical lateral loads exists, the Geological Strength Index, per the Governing Specifications, is to be determined for rock mass deformation. A minimum of three unconfined compressive strength tests or three point load testing groups shall be attempted per major rock type encountered.
The type of foundation selected for a substructure unit shall be based on the findings from the core borings obtained.

2.3.2.2 Approach Embankments

At least one boring shall be taken at the point of highest fill; usually the borings taken for the bridge abutment will satisfy this purpose. If settlement or stability problems are anticipated, as may occur due to the height of the proposed embankment and/or the presence of poor foundation soils, additional borings shall be taken in the suspect area. Extend borings below any unsuitable founding material.

Sampling criteria is the same as for bridges; however, undisturbed sampling may be taken where N-Values are greater than 4 in suspect areas.

2.3.2.3 Retaining Walls and Miscellaneous Structures

The maximum interval between borings is 100 FT, as close to the structure's foundation as possible. Borings shall be extended below the bottom of the foundation at least 10 FT into competent material and SPT sampling on 2.5 FT intervals shall be performed. This applies to proprietary systems, Geosynthetic Reinforced Soil – Integrated Bridge System (GRS-IBS), as well as precast and cast-in-place wall sections. Sampling and testing criteria are the same as for bridges.

2.3.2.4 Slope Stability

Instability of approach embankments has been a very costly problem. A stability analysis shall be performed on approach embankments. The Geotechnical Engineer can waive the need for stability analysis for approach embankments 10 feet or less, above the surrounding ground, that are supported by firm ground. The minimum factor of safety of 1.5 shall be obtained for all failure surfaces that intersect a bridge substructure. Otherwise the minimum factor of safety of 1.3 shall be used for embankments. Should the above factors of safety not be attainable by flattening the slope, then the presence of the piles may be used. Some concerns that shall be addressed during this geotechnical analysis are:

- excess pore pressure during construction,
- ground water seepage during wet weather on hillsides on which the approach embankments are founded,
- where pre-existing slides in natural hillside slopes have occurred, and
- rapid draw down results in a factor of safety less than 1.1.

The hydraulic and scour effects on the stability of slopes adjacent to bridges are also a concern and shall be analyzed at the discretion of the Geotechnical Engineer and found to have a minimum factor of safety of 1.1.

2.3.3 Geotechnical Tasks

This section is designed to present information in the same sequence, as it would occur during project development. A general outline of the tasks that should be performed by a Geotechnical Engineer during a project is discussed. Methods of subsurface investigation, analyzing data and solving problems are not discussed in detail.

2.3.3.1 Planning, Development, and Engineering Phase

- Prepare geotechnical scope of services for consultant projects.
- Review existing information.
- Perform field reconnaissance of site and existing structures.
- Plan and supervise field investigation program, field and laboratory testing.
- Visually verify soil and rock types and strata depths, and prepare draft boring logs.
- Arrange an informal meeting where the draft logs, foundation type(s) and tip elevations are discussed with the Design Engineer.
- Analyze all data available.
- Prepare preliminary geotechnical report summarizing available data and provide recommendations.

- Identify potential construction requirements and problems (e.g., predrilling and stabilization requirements.)
- Evaluate Vibration and Sound Impact per Chapter 12 of "Transit Noise and Vibration Impact Assessment", FTA-VA-90-1003-06 for pile driving and drilled shaft drilling when structures are closer than 75 feet to other structures.

2.3.3.2 Project Design Phase

- Perform additional field investigations and provide additional or revised recommendations if called for in the preliminary geotechnical report or if the project has substantially changed since earlier investigations.
- Design and, if applicable, perform load test programs or special instrumentation monitoring as deemed necessary.
- Review plans, special provisions and/or supplemental specifications for compliance with the geotechnical report.
- Perform constructability review with respect to geotechnical activities. Identify potential construction conflicts and recommend changes to minimize potential construction problems and claims. Determine if specialized construction techniques are necessary such as pre-drilling. Consider other impacts such as vibration and sound levels, etc.
- Finalize Geotechnical Report.

2.3.3.3 Construction Phase

- Establish construction criteria for geotechnical portions of project.
- Inspect construction procedures to assure compliance with design and specifications.
- Assist in design, installation, performance, monitoring, and evaluation of load test programs and/or instrumentation systems.
- Assist in solution of unforeseen foundation and/or roadway geotechnical problems.

2.4 STRUCTURAL SYSTEM SELECTION

The WVDOH encourages diversity in studying a wide range of bridge systems for each project. However, the number and complexity of the systems studied will vary for each specific site. A bridge structural system consists of a superstructure and substructure.

All feasible superstructure types must be considered in the preliminary phases of the project. Haul lengths and weight limits should be verified by the Designer by contacting suppliers in the area. Prior to the submission of the Span Arrangement, the Designer shall meet with the Bridge Project Manager to discuss the span arrangement alternatives that will be included in the submission. In the case of a bridge design by a consultant, this meeting is referred to as the Pre-Span Arrangement meeting. At this meeting, the Designer and the Bridge Project Manager will make decisions on what superstructure, abutment, pier types and span arrangements should be studied in the span arrangement phase of the project. The following sections discuss some of the steel and concrete superstructure types that are used by the WVDOH. All structures studied shall accommodate their anticipated movements. In this regard, jointless bridges are to be used whenever possible. However, for very long structures, the Bridge Designer shall minimize the number of intermediate expansion joints.

The substructure consists of abutments and piers founded on various types of foundations. Common abutment and pier types along with foundation types are also described later in this section.

2.4.1 Steel Superstructure Types

Steel superstructures should be considered for any span length ranging from 20 to 650 FT or more. Generally, the following table (Table 2.4.1) can be used as a guideline for selecting steel superstructure types.

SPAN LENGTH (FT)	SUPERSTRUCTURE TYPE
20 to 100	Rolled Beams
60 to 130	Rolled Beams with Cover Plates
80 to 400	Welded Plate Girders
200 to 400	Box Girders
400 to 900	Truss
500+	Cable Stayed
650+	Tied Arch

Table 2.4.1

The superstructure should be designed such that the structure has redundant load paths and is not considered fracture critical. Some designs, especially truss and tied arch designs, are generally, by their very nature, fracture critical. As defined in the Governing Specifications, a Fracture-Critical Member (FCM) is a "*Component in tension whose failure is expected to result in the collapse of the bridge or the inability of the bridge to perform its function.*" The Designer is to declare at Span Arrangement or TS&L if the structure is fracture critical. Fracture critical design must be approved by the Director of Engineering Division. Design calculations, welding procedures, and material specifications can be incorporated into the project to make the use of these superstructure types acceptable.

Unpainted weathering steel in bridge construction has been shown to be a cost effective choice when the site conditions are appropriate for its use. The cost savings associated with the use of weathering steel is realized both in initial construction and in long-term maintenance of the structure. Unpainted weathering steel will be used for construction whenever appropriate. For a more detailed discussion, see Section 3.3.9.

High performance steel should also be considered when determining viable superstructure alternatives. It has been found to not only provide cost savings but also increase the serviceability of a structure. For a more detailed discussion, see the WVDOH's policy on high performance steel, Section 3.3.1.2.

Painted steel may be used where the use of weathering steel is not permitted. These locations include:

- Wet environments
- Industrial areas where concentrated chemical fumes may drift directly onto the structure
- Grade separations resulting in "tunnel-like" conditions
- Low level water crossings
- Other locations as determined by the Bridge Project Manager

The following section discusses the various types of steel superstructure types and guidelines for when to consider them.

2.4.1.1 Rolled Beams

Rolled beams should be considered for any span length ranging from 20 to 100 FT. With cover plates, the span range of rolled beams can be extended to 130 FT. However, only end bolted cover plates shall be used (see Figure 2.4.1.1). The Designer shall determine the availability of any rolled section considered, including lengths and grade of steel.

The Designer should minimize the number of beam lines. Rolled beam bridges should have a minimum of three stringer lines.

Continuous spans shall be used for multi-span bridges. The ratio of the length of the end spans to the intermediate spans should preferably be 0.75.

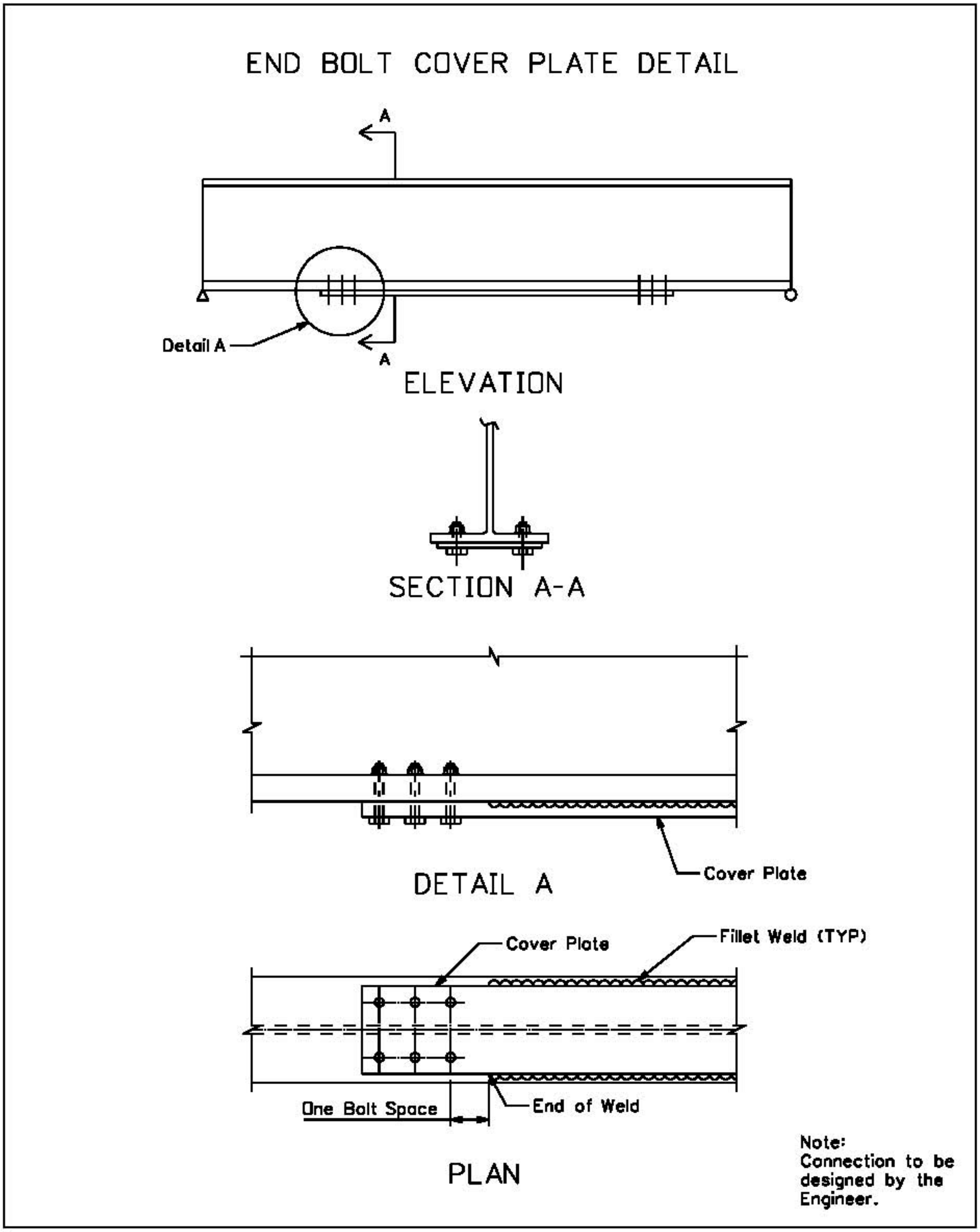

END BOLT COVER PLATE DETAIL
A
A
Detail A
ELEVATION
SECTION A-A
DETAIL A
Cover Plate
Cover Plate
Fillet Weld (TYP)
One Bolt Space
End of Weld
PLAN
Note:
Connection to be
designed by the
Engineer.

Figure 2.4.1.1

2.4.1.2 Plate Girders

Plate girders should be considered for any span length ranging from 80 to 400 FT. The Designer shall carefully evaluate the bridge cross section to ensure appropriate girder spacing. Substantial cost savings may be realized early in the design process. The following shall be considered during the span arrangement study:

- Use of wider girder spacing to eliminate one girder line, in some cases, may increase the total weight of the steel. However, the savings realized through fabrication of one less girder, fewer cross frames and bearings, as well as savings realized through shorter erection time will often offset an increase in raw steel cost. Three girder lines is the minimum unless the system is structurally redundant and not fracture critical.
- Consultation with fabricators and erectors is recommended to assess the fabrication and erection costs of the girders.

Generally, continuous spans shall be used for multi-span bridges. The ratio of the length of the end spans to the intermediate spans should preferably be 0.75. If the end span to intermediate span ratio is small, anchored end spans shall be considered to eliminate any uplift problems at the abutments. The Bridge Designer should also consider the economics of a system designed span by span (i.e., simply supported for dead load and continuous for live load).

Detailing interior and exterior girders the same is often desirable for curved bridges with three to five girder lines and for most tangent bridges. Therefore, when designing tangent bridges, consider "balancing" the total factored design moment for interior and exterior girders to yield similar performance. Balancing factored design moments is accomplished by adjustment of girder spacing and overhang dimensions. This type of study may be efficiently performed using simple line girder analyses. For curved structures with five or more girders, consider grouping the girders into two similar designs, one for girders interior of the centerline of the bridge and one for girders exterior to the centerline of the bridge. Consult with fabricators to ascertain the least cost approach.

Limit girder spacing to 15 FT for typical girder structures. For girder/sub-stringer framing arrangements, the main girders may be efficiently spaced at 20 to 22 FT. Large girder spacings may cause an increase in the structural thickness of the deck slab. Therefore, evaluation of larger girder spacings must be accompanied by an evaluation and cost analysis of the deck slab. Steel fabrication and erection savings may be partially offset by an increase in deck cost.

Optimize the girder weight by investigating various web depths.

The minimum web thickness for plate girders is $^7/_{16}$ IN. Increment the web thickness by a minimum of $^1/_{16}$ IN. It is generally more economical to maintain a constant web thickness throughout a project. However, the web thickness may be varied at field splices, or less desirable, at shop splices. The Designer shall consult with a steel fabricator to determine the most economical location of a splice, and whether or not the added cost of additional web thickness will be offset by changing the web thickness.

2.4.1.3 Box Girders

Steel box girders can be considered as an alternate for steel plate girders for span length ranging from 200 to 400 FT.

A box girder has two or more vertical or inclined webs, a continuous bottom flange plate connecting the webs, and narrow top flange plates on each web. The box girder cross-section having a hollow rectangular or trapezoidal section is a suitable candidate in an urban setting where aesthetics play an important role in bridge type selection. The closed section of a box girder has high torsional resistance, which makes them economical for curved bridges.

2.4.1.4 Trusses

Trusses can be used for bridges over navigable river crossings with spans from 400 to 900 FT. The main structural elements of a typical bridge truss consist of stringers, floor beams, top chord, bottom chord, vertical and diagonal members of the main longitudinal trusses, lateral bracings and sway bracings. Chord members carry the bending moment while the diagonals carry the shear. Axial loads are the predominant forces in all truss members.

Based on aesthetics and the object of reducing the total truss weight, it is preferable to use a curved chord truss rather than a truss with parallel chords. Truss bridges can be designed as simple or continuous spans. Simple span trusses for multi span bridges are recommended only when problems due to excessive foundation settlement is anticipated. For a continuous truss bridge with three or more spans, a common method of construction utilizing cantilevered end spans that support the central suspended span can be used.

The stringers can be designed similar to steel rolled beam bridge members. The floor beams are generally plate girders with variable plate sizes. Generally, the truss members are composite box sections made of welded plates and the bracing members are rolled W, T or channel shapes. The use of high performance steel shall be investigated in the span arrangement study for main truss members, stringers, and floor beams.

2.4.1.5 Cable Stayed

Cable-stayed bridges are competitive for medium and long spans (500 to 1500 FT). The superstructure, consisting of a concrete deck on steel girders, is supported at several intermediate points by cables radiating from one or more towers. Generally, a cable-stayed bridge system consists of a three span structure with a long main span and two smaller end spans.

2.4.1.6 Tied Arch

Tied arch bridges can also be used for medium and long spans (650 to 1700 FT). A tied arch may also be used as a center span in conjunction with plate girder approach spans. The high horizontal reactions induced in large span arches are carried by the tie-girder, which is essentially a tension member connecting both ends of the arch itself. The rib of an arch bridge can be either a girder member or a truss.

2.4.2 Concrete Superstructure Types

Concrete superstructure types should be considered for any span length ranging from 20 to 650 FT or more. Generally, the following table (Table 2.4.2) can be used as a guide for selecting concrete superstructure types.

SPAN LENGTH (FT)	SUPERSTRUCTURE TYPE
up to 30	Slab Bridges
20 to 100	Box Beams
35 to 165	I - Girders
165 to 300	Post Tensioned I - Girders (Drop-In)
100 to 180	Segmental Concrete Boxes (Span-By-Span)
150 to 450	Segmental Concrete Boxes (Precast)
450 to 700	Segmental Concrete Boxes (Cast-In-Place)
500+	Cable Stayed

Table 2.4.2

The possible exceptions to the use of precast concrete beams are: structures with severe horizontal curvature, vertical curvature, limitations on structure depth, skew greater than acceptable limits, and restrictions on transportation.

Concrete compressive strengths for commonly used precast beams shall be no less than 6000 PSI (5500 PSI for WVDOH Standard Box Beams) at release (f'_{ci}) with a minimum final compressive strength of 8000 PSI (f'_c).

High strength concrete (HSC) should also be considered when determining possible concrete superstructure alternatives. Precast beams may be designed using high strength concrete with a final compressive strength of up to 10000 PSI and a release strength of up to 9000 PSI with approval of the Director of the Engineering Division. HSC allows engineers to: design structures with smaller beams when clearance criteria needs to be met, reduce dead loads for more cost efficient substructures, and increase span lengths over conventional concrete.

The following sections discuss the various types of concrete superstructure types and guidelines for when to consider them.

2.4.2.1 Slab Bridges

This superstructure type consists of a reinforced concrete slab with the main reinforcing parallel to the direction of traffic. This type of structure may be economical for very short span bridges, generally less than 30 FT in length.

2.4.2.2 Box Beams

For short span bridges of 100 FT or less, prestressed concrete box beams may be considered an economical solution.

Three basic cross-sectional configurations are commonly used. They are:

- adjacent box beams with or without a hot-laid bituminous concrete (HLBC) wearing surface,
- adjacent box beams with a composite reinforced concrete deck, and
- spread box beams with a composite reinforced concrete deck.

Note: All bridges, including adjacent box beam bridges, on routes designated as coal haul roads and/or subject to heavily loaded trucks shall have composite reinforced concrete decks.

Factors involved in the choice of box beam configuration design should include but are not limited to: economics, traffic type and volume, time constraints, and method of construction (whether by contract or state construction crews which generally have limited construction capabilities). The Bridge Designer should verify capabilities with the District prior to designing a structure that will be built with state forces.

2.4.2.3 Prestressed Concrete Beams

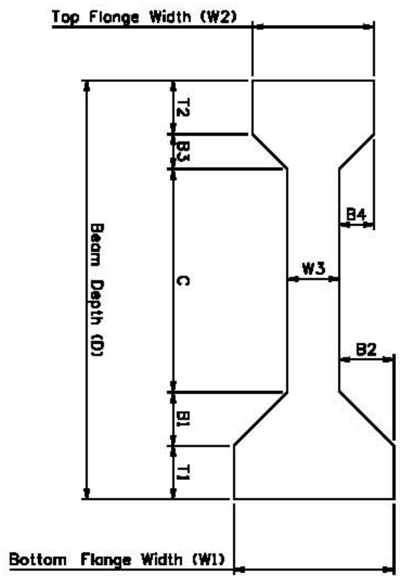
AASHTO Type I, II, III, IV or Type IV Modified prestressed concrete beams should be considered for bridges with spans from 25 to 145 FT. The maximum span length is based on the haul capacity for a particular project site and shall be verified with a prestressed concrete beam supplier familiar with the project location. For continuous spans, the bridge system shall be designed simply supported for dead load and continuous for live load and superimposed dead load only. The Designer should minimize the number of beam lines. Prestressed concrete beam bridges should have a minimum of three stringer lines.

The design of all structures that utilize prestressed concrete I-beam sections will be accomplished using one of the beam sections from Figure 2.4.2.3. AASHTO Type V and Type VI sections shall not be used unless approved by the Director of Engineering Division.

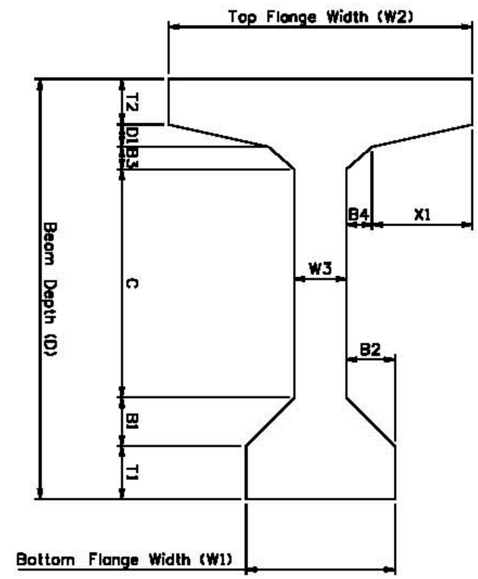
Alternate beam sections may be used for special design situations. Proposed sections, other than those shown in the following tables must also be approved by the Director of Engineering Division.

Prestressed concrete beams shall be spaced to optimize girder size and strand usage. Examples of beam types, spacings and span lengths are shown in Table 2.4.2.3.

WVDOT-DOH STANDARD PRESTRESSED CONCRETE I-BEAM SECTIONS



AASHTO I-BEAM
Typical-Type II, III & IV



AASHTO I-BEAM
Typical-Type IV MOD, V* & VI*

Beam Designation	Top Flange Width (IN) W2	Bottom Flange Width (IN) W1	Depth (IN) D	Depth (IN)						Flange (IN)			Web Thickness (IN) W3	Basic Beam Properties		
				T2	D1	B3	C	B1	T1	X1	B4	B2		Area (IN^2)	Y_b (IN)	I_{xx} (IN^4)
II	12	18	36	6	-	3	15	6	6	-	3	6	6	369	15.8	50,980
III	16	22	45	7	-	4½	19	7½	7	-	4½	7½	7	560	20.3	125,390
IV	20	26	54	8	-	6	23	9	8	-	6	9	8	789	24.7	260,730
IV MOD	36	26	60	4	2	3	34	9	8	11	3	9	8	860	28.8	384,248
IV MOD	36	26	66	4	2	3	40	9	8	11	3	9	8	908	31.6	491,660
IV MOD	36	26	72	4	2	3	46	9	8	11	3	9	8	956	34.4	615,361
IV MOD	36	26	78	4	2	3	52	9	8	11	3	9	8	1,004	37.3	756,222
IV MOD	36	26	84	4	2	3	58	9	8	11	3	9	8	1,052	40.2	915,113
V*	42	28	63	5	3	4	33	10	8	13	4	10	8	1,013	31.9	521,180
VI*	42	28	72	5	3	4	42	10	8	13	4	10	8	1,085	36.4	733,320

* Use only when specifically approved by the Director of Engineering Division.

Figure 2.4.2.3

		Beam Spacing (FT)				
		14	12	10	8	6
AASHTO Type	I	25	30	35	40	45
	II	40	45	50	55	60
	III	60	65	70	75	85
	IV	75	85	90	95	105
	V	95	100	110	120	125
	VI	105	115	120	130	135
Type IV Modified	60 IN	85	95	100	110	120
	66 IN	95	100	110	120	125
	72 IN	100	110	120	125	135
	78 IN	110	115	125	130	140
	84 IN	115	125	130	135	145

Table of Approximate Maximum Span Lengths (FT)

NOTE: These values are approximate and should be used for preliminary design purposes only. These values shall not be used for final design. The designs were based on single span (simply supported) bridges with 32 IN Type F barriers, no sidewalks and utilizing concrete with a release strength (f'_{ci}) of 6000 PSI and a final strength (f'_c) of 8000 PSI.

Table 2.4.2.3

2.4.2.4 Post-Tensioned I-Beams (Drop-In)

Using post-tensioned drop-in spans can increase span lengths for prestressed concrete beams. The drop-in segments will be field spliced with pier segments and then the entire girder will be post-tensioned. At the field splice locations, temporary shoring towers or strongbacks may be required.

2.4.2.5 Segmental Concrete Boxes

Segmental concrete boxes are an economical solution for bridges with span lengths over 100 FT and where repetition of the box fabrication can be achieved. There are three methods of construction for segmental concrete: span-by-span, balanced cantilever, and cast-in-place. Each offers advantages in different situations.

2.4.2.6 Cable Stayed

Cable-stayed bridges are competitive for medium and long spans (500 to 1500 FT). The superstructure, consisting of a concrete deck on prestressed concrete beams, is supported at several intermediate points by cables radiating from one or more towers. Generally, a cable-stayed bridge system consists of a three span structure with a long main span and two smaller end spans.

2.4.3 Abutment Types

Abutments are structures positioned at the beginning and end of a bridge, which support the superstructure and approach roadway and retains the earth embankment.

Abutments can be classified into the following five types:

- Wall Type Abutment
- Pedestals
- Stub Abutment
- Integral Abutment
- Semi-Integral Abutment
- Geosynthetic Reinforced Soil – Integrated Bridge System (GRS-IBS)

2.4.3.1 Wall Abutment

This type of abutment, also known as a full height abutment, may be used when right-of-way is critical or the site does not permit a longer bridge with sloping embankments. Span lengths can be reduced using a wall type abutment. The footing may transfer loads by direct bearing (spread footing) or it may be supported on piles or drilled caissons.

The maximum exposed face should generally be 30 FT, measured from gutter line to ground line in the profile view. Taller heights may be permitted, with permission of the Bridge Project Manager, when the negative effects of a tall structure on the traveling public or aesthetics are not a governing factor. Otherwise, where walls greater than 30 FT are required, a stepped (terraced) wall configuration shall be used.

2.4.3.2 Pedestals

The beam seat is supported on columns/drilled caissons or pedestals resting on individual footings. This configuration is useful for meeting unique construction problems, e.g., widely varying elevations of competent rock.

2.4.3.3 Stub Abutment

Stub abutments are relatively short abutments that resemble wall type abutments. These abutments are generally placed on the approach embankment and are supported on rock, piles or drilled caissons.

2.4.3.4 Integral Abutment

Integral abutments are generally short abutments supported on a single row of piling. These abutments, like stub abutments, are generally placed on approach embankments and are well suited for bridges with limited thermal movements. The ends of the bridge beams are cast directly into the abutments, thereby eliminating the need for bridge deck expansion devices.

This abutment type can be used in combination with MSE walls to provide the benefits of a wall type abutment while satisfying the preference for using jointless bridges.

See Section 3.9 for limitations on the use of integral abutments.

2.4.3.5 Semi-Integral Abutment

Semi-integral abutments can be either wall or stub type abutments. The difference between a semi-integral and an integral abutment is that for semi-integral abutments, the beams are cast in a closure diaphragm that is structurally independent from the stem. This type also eliminates the need for bridge deck expansion devices.

See Section 3.9 for limitations on the use of semi-integral abutments.

2.4.3.6 Geosynthetic Reinforced Soil –Integrated Bridge System Abutment (GRS-IBS)

GRS-IBS Abutments were initially develop by FHWA and can provide an economic alternative to other abutment types especially where adjacent box beams are used and scour is not considered to affect the foundations. The GRS-IBS abutment type consist of high performance woven geotextile and open graded stone such as # 8 crushed stone. For low abutment heights, this abutment type can save time since concrete curing time is eliminated. The integrated approaches provide the reinforced backfill required for bridges and can eliminate the need for approach and sleeper slabs on low ADT bridges. Since the bridge is supported on the layers of GRS and no deep foundations are needed, “the bump at the end of the bridge” is eliminated. Standard 8 IN split face masonry block should be used as the facing.

It is important to place GRS-IBS abutments adjacent to non-scourable streams (hard bedrock is exposed), or where the existing abutments can provide a scour wall, or where the Reinforced Soil Foundation (RSF) can be placed below the scour depth. All GRS-IBS bridges locations shall be approved by the Director of Engineering Division.

The design of GRS-IBS abutments is empirically based on a service limit bearing resistance of 4,000 PSF provided by the criteria presented in "Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide" (Publication No. FHWA-HRT-11-026) is followed.

2.4.3.7 Wingwalls

Wingwalls are walls on either side of an abutment used to retain the roadway embankment. Wingwalls can be constructed of cast-in-place concrete or MSE walls and shall be designed as retaining walls. They shall be sufficiently sized to prevent the roadway embankment from spilling onto the abutment seats or into the clear area under the bridge.

U-shaped or turned-back wingwalls are commonly used in embankment situations and straight wings are used in cut sections. Flared wingwalls between these extremes can also be appropriate based on site conditions. The Designer must study the existing and proposed surfaces to determine which type of wingwalls best fits the site. Wingwalls with a tapered bottom surface shall be avoided due to compaction difficulties beneath the wall. The top surface of U-shaped wingwalls may be tapered parallel to the roadway slope to match the finished grade.

2.4.4 Pier Types

Piers are intermediate supports in a multi-span bridge system. All feasible pier types must be considered in the preliminary phases of the project.

2.4.4.1 Cap-and-Column Type Piers

Cap-and-column type piers have two or more circular or rectangular columns connected on top with a cap (a reinforced concrete beam that supports the superstructure). Generally, the pier cap ends will be cantilevered. For columns greater than 100 to 150 FT, the use of a compression strut at mid-height, similar to the pier cap, shall be investigated. The individual columns will be supported on an appropriate foundation.

2.4.4.2 T-Type or Hammerhead or Wall Type Piers

T-type or Hammerhead piers have a deep rectangular tapered beam carrying the superstructure supported on a single wide rectangular or oval column in the middle. For wall type piers, the width of the rectangular column will be very close to the length of the pier cap. The single column will be supported on an appropriate foundation. In some situations, the feasibility of using a single large circular column instead of a wide rectangular or oval column has to be investigated during the preliminary design phase of the project.

2.4.4.3 Post-Tensioned Concrete/Integral Pier Caps

To satisfy the vertical clearance requirement beneath a pier cap, a post-tensioned or integral pier cap shall be investigated.

2.4.4.4 Steel Pier Caps

Steel pier caps are fracture critical. If used, the design shall allow for reasonable access to the interior for future maintenance, inspection and repair.

2.4.5 Foundation Types

All feasible foundation types must be considered in the preliminary phases of the project. The WVDOH's policy is to found all new bridge foundations on rock. However, bridges may be allowed to be supported on Intermediate Geomaterial (IGM) at the discretion of the Geotechnical Engineer.

2.4.5.1 Spread Footing

Spread footings have been found to be economical for depths to 20 FT. Preferably, spread footings should be founded on rock. However, spread footing foundations may be supported on Geosynthetic Reinforced Soil-Integrated Bridge Systems or MSE retaining wall backfill where allowed by the Director of Engineering Division.

In situations where a cofferdam may be required for the construction of a spread footing, the cost of the cofferdam shall be included when comparing foundation options. Spread footing foundations shall be placed below the scour depth. Other concerns to consider include the stability of approach embankments, differential settlement, etc.

2.4.5.2 Piling

Piling must be designed for both axial and lateral loads as appropriate. As a minimum, piling shall be sized using a wave equation program such as GRLWEAP. Loads may include external (non-structure related) as well as structural loads. For example, pile foundations might be used to enhance stability of the approach embankment if the embankment factor of safety is questionable.

Piling to competent rock will normally be designed as end bearing and driven to refusal. Additional loading from negative skin friction (downdrag forces), resulting from embankment settlement, must be added to that from structural loads and any other external loads. Battered piles may be required to help resist lateral loads but shall be avoided wherever possible. Pile tips shall be used for refusal on rock. The cost for pile tips shall be included in the cost estimate for the pile foundation.

With permission of the Bridge Project Manager, friction piles and end bearing piles on non-competent rock strata may be considered when site-specific conditions warrant and when all other concerns (such as settlement or scour) are addressed.

The minimum piling length shall be 10 FT. See Section 3.12.3 for further discussion.

For integral abutments, single-line piling systems shall be used, predrilled 15.0 FT deep using 1.0 FT diameter for soil or 2.0 FT diameter for rock.

Foundations supported on piling should be placed below the scour depth. When the bridge scour computations indicate that the steel piling may be exposed due to scour, then the piling cap placement must be designed in accordance with Section 3.12.3.

2.4.5.3 Drilled Caissons

Drilled caissons provide: superior scour protection versus traditional steel piling, greater resistance against high lateral and uplift loads, and accommodation of site concerns associated with the pile driving process (vibrations, interference due to battered piles, etc.), and in some cases exclude the need of cofferdams. In addition, drilled caissons may eliminate the need of caisson caps, for certain configurations such as single or multiple column piers.

Drilled caissons shall be designed using soil-structure intersection software such as L-PILE. The rock socket length shall be determined as to the second node that crosses the zero deflection line in the service limit state. For strong rock both end and side resistance can be added directly. For soft rock, such as claystone and soft siltstone, only end resistance shall be used.

Construction techniques shall be in accordance with the Standard Specifications. These include, but are not limited to, pre-installation core holes, providing a test hole for shafts 10.0 FT and larger in diameter and crosshole sonic logging (CSL) testing.
Results from the CSL testing may show inadequate structural integrity and continuity. Further investigations such as core drilling for each of the unacceptable caissons would then be required, causing construction down time and added expenses.

2.5 ADDITIONAL DESIGN CONSIDERATIONS

2.5.1 Curved Bridges

Bridge Designers are cautioned to design curved structures for all relevant forces as specified in the Governing Specifications, even if the girders are straight and the deck is curved.

For moderately curved bridges, the use of straight steel girders or prestressed concrete beams with spacings satisfying the minimum and maximum deck overhang requirements shall be investigated.

Slab bridges, cast-in-place and precast segmental bridges are other options for curved concrete bridges.

2.5.2 Aesthetics

The Bridge Designer shall determine and offer proposals of aesthetic treatment to the Bridge Project Manager in charge of the project.

General desirable traits include:

- uniform superstructure depth,
- homogenous girder material throughout the structure,
- symmetric span arrangements, and
- orientation of substructure units should be aesthetically consistent with the features they cross and the overall bridge layout.

For additional aesthetic requirements, see the Governing Specifications.

2.5.3 Approval of Vendor Supplied Products

All products designed and supplied by the Contractor or their Vendor shall be subject to approval of the Bridge Project Manager and the Materials, Control, Soils and Testing

Division. These products include, but are not limited to: culverts, proprietary retaining walls, bearings, expansion devices, inspection walkways, stay-in-place forms and any prefabricated item used on a structure other than those specifically designed and detailed in the contract plans.

If the product is not specified in the Standard Specifications, the Designer is responsible for writing a Special Provision to describe the product and the criteria it has to meet. This shall include directions to the Contractor as to the necessary information to submit for approval by the Engineer. The following is a partial list of items the Designer is to provide the Vendor: all applicable loads, critical dimensions, design method to be used (LRFD) and any additional information that may be required for the product to be designed and detailed.

Vendor submissions should include items such as design calculations, design method, detailed drawings, construction sequence, induced loads, etc. and shall be stamped by an Engineer registered in West Virginia.

When a proprietary item is proposed, the Designer shall justify the benefits of the product and show that no other alternate exists. Proprietary items may also be warranted when a new technology or product is being evaluated. The use of the proprietary item shall then be submitted for approval to the Bridge Project Manager. The Bridge Project Manager will then submit the request to the Deputy State Highway Engineer, Development, who will then forward it to the Federal Highway Administration (FHWA) for approval.

2.5.4 Protective Fencing

It shall be the policy of the WVDOH to evaluate the need for screening on bridges and overpasses when:

- a new structure is being designed,
- an existing structure is being renovated, and
- a pattern of accidents or public complaints indicates that there is a problem with objects or debris being thrown or dropped from an existing overpass or viaduct.

The intent of this section is to assist the designer in identifying those bridges where the probability of occurrence is high or where problems are known to exist and to assure that reasonable protective measures are taken at those locations. It will be the responsibility of the Bridge Designer to document the decision to, or not to install screening, the factors influencing the decision and the reasons for the type of screening chosen. This decision shall be included in the TS&L Report for review by the Bridge Project Manager.

Factors that shall be considered in the decision to install, or not to install, screening shall be as follows:

- Presence of a sidewalk.
- The proximity to a school, playground or neighborhood that may generate a significant number of children who may play on or around the structure. In addition to protecting those below, the screening may prevent children from climbing on the railing and falling off the structure.
- The presence of a transportation facility such as a roadway, a railroad or a navigable waterway below the overpass or bridge. In the case of a railroad, or navigable waterway, the frequency and sensitivity of the traffic passing under the structure shall be taken into account.
- Requirements of the entity or agency over which the structure passes, such as a railroad, the Corps of Engineers or the National Park Service.
- Effect on aesthetics or on maintenance, including inspection, snow removal or ice control or navigation lights, and the maintenance of the screening itself.
- Effects on the safety of vehicles crossing the structure, especially where speeds are high.

2.6 MISCELLANEOUS STRUCTURES

2.6.1 Timber Structures

Timber structures should not be considered as a superstructure type unless the project is designated by the WVDOH as such. Timber structures may be considered for pedestrian bridges.

2.6.2 Pedestrian Structures

Pedestrian bridges should undergo the same design evaluations as vehicular structures. All applicable superstructure types, including timber, shall be considered. In addition, pedestrian bridges should consider aesthetics, from both the user’s standpoint as well as the view of the structure by motorists. See AASHTO *Guide Specifications for Design of Pedestrian Bridges*.

2.6.3 Buried Structures

Buried structures such as box culverts and culverts of other configurations may be designed as precast or cast-in-place, or the contract plans may leave the option to the contractor.

All cast-in-place culverts shall be fully designed and detailed in the contract plans. When precast products are specified, the Designer shall also specify all necessary design criteria including design method. Certified design calculations and drawings shall be submitted to the Engineer for approval for precast products.

The Designer should make every effort to use single cell boxes; single cell openings with clear spans up to 16 FT are routinely used. Box culverts of three or more cells should be avoided, due to high construction and maintenance costs. However, high fill heights or other restraints can make three or more cell boxes cost effective.

Future maintenance of the boxes must be considered in the proposed layout. Such considerations should include a maintenance road to the inlet and outlet of the box and debris racks.

Buried structures with 3 FT or less of fill shall be designed with epoxy coated reinforcing steel in the top slab of the structure.

Due to stream mitigation requirements, some box culvert bottom slabs may need to be buried and a natural streambed developed. The Bridge Designer should check to see if this is required on their project.

Culverts shall be designed for discharges as required by the *WVDOH Drainage Manual* and Section 501 of the Design Directives.

2.7 BRIDGE REHABILITATION

In the course of maintaining the State's highway system to accepted standards, it becomes necessary to rehabilitate or replace structures that have become either functionally or structurally obsolete or physically deteriorated to the point that structural capacity is significantly impaired. If rehabilitation is chosen, the durability of the repaired component shall be at least as durable as the original member. The Designer shall verify that the existing bridge components are not adversely affected by the new "global conditions" created from the rehabilitation. The extent of bridge rehabilitation is based on an assessment of current conditions, estimates of future travel demands, and anticipated capital and maintenance investments that will be realized through a specific year. The District Bridge Engineer plays a key role in the selection of bridges for replacement or rehabilitation. Cost estimates should be done to help determine if either replacement or rehabilitation of a structure is needed. Inspection reports are a good basis for determining rehabilitation needs. These reports are available from the Maintenance Division. However, these reports should not be the sole source used by the Designer to develop the contract plans. Generally, a detailed inspection, by the Designer, is required along with material testing. This additional inspection work must be sufficient to detail and quantify the necessary repairs.

See DD-604 and DD-605 for additional information pertaining to bridge rehabilitation.

2.7.1 Bridge Inspection

Bridges are inspected on an interval based on their condition or type. The current interval for a Routine Inspection required for all structures by the National Bridge Inspection Standards (NBIS) is 24 months. The WVDOT-Division of Highways (WVDOT-DOH) policy requires an In-depth Routine Inspection at a 72 month interval. Additionally, WVDOT-DOH has a policy that has been approved by the Federal Highway Administration (FHWA) that allows bridges that are in good condition and meet certain other criteria to have a Routine Inspection interval of 48 months and an In-Depth Routine Inspection interval of 96 months. Bridges that may warrant a specific concern may require a Special Inspection at an interval less than 24 months.

The various inspection types covered in the WVDOT-DOH *Bridge Inspection Manual 2014* (WVBRIM) are:

- Inventory Inspection
- In-Depth Routine Inspection
- Routine Inspection
- Special Inspection
- Damage Inspection
- Underwater Inspection

This WVBRIM is available in the Bridge Evaluation Section of Maintenance Division and incorporated by reference various documents including the following:

- AASHTO *Manual for Bridge Evaluation, 2nd edition 2010 (2011, 2013 and 2014 Interims)*
- U. S. Department of Transportation *Bridge Inspector's Reference Manual 2002 (2006 and 2012 Revisions)*
- NBIS

2.7.2 Widening

Widening is usually considered for deck bridges supported on steel or concrete beams or girders. The following items should be addressed in a widening project on all components:

- Materials used in the construction of the widening shall preferably have the same thermal and elastic properties as the existing.
- The widening of the structure should be accomplished in a manner such that the new construction blends with the existing structure.
- The main load carrying members should be proportioned to provide similar longitudinal and transverse load distribution characteristics as the existing

structure. The final design shall result in a structure with a uniform stiffness over the entire cross section.

- The construction sequence and degree of interaction between the widening and the existing structure after completion shall be fully considered in determining the distribution of the dead load for design of the widening and stress checks for the existing structure.
- The design of the widening shall conform to the Governing Specifications. This shall include the verification of all existing components using LRFD.
- The use of beams that are the same type as the existing beams are preferred.
- All dimensions that affect the details that the Designer is preparing shall be confirmed by the Designer or the Contractor. The dimensions that are to be checked by the Contractor must be called out for in the contract plans.
- All horizontal and vertical clearances shall be checked. For decks with normal crown or superelevation, the new fascia beam may become the lowest point on the deck, so vertical clearance must be checked.
- The widened deck section should be structurally attached to the existing deck and the transfer of moment and shear shall be provided using dowels with sufficient splice laps. A concrete shear key is not necessary but a roughened construction joint should be used. A closure pour should be generally used when construction staging does not prohibit its use.
- A construction sequence detail, including maintenance of traffic details, shall be shown on the preliminary bridge plan submittal for all projects utilizing phased construction. In addition, the final plans shall include a complete outline of the order of construction.
- Changes to existing drainage must be investigated.

2.7.3 Rehabilitation Techniques

The following sections describe various methods for repairing and rehabilitating bridges. These are in no way meant to limit the Designer to these methods but to give guidance in accepted procedures. All plans developed for rehabilitation shall include appropriate details to comply with AASHTO Standard Specifications for Seismic Design of Highway Bridges.

The following shall be considered on all rehabilitation projects:

- Structural integrity and general acceptability of design
- Future maintenance considerations
- Hydraulic considerations (waterway opening, backwater effect, etc.)
- Geometric safety (roadway width, guardrail, etc.)
- Right-of-way clearance
- Department of Natural Resources (DNR) and Corps permit clearance
- Erosion Control
- Suitability of the sequence of construction required by the design

All material used in any rehabilitation or repair project shall be in accordance with the Standard Specifications and supplemented by project specific special provisions, as necessary.

2.7.3.1 Steel

Repair of steel members may be necessary to correct deficiencies associated with cracking, corrosion, and fatigue. This includes cracking of joints and welded connections, partial length cover plates, and brackets. Fracture-critical members require special assessment because their failure would be expected to result in bridge collapse. All repairs shall consider the dead load that exists in original members and the original members shall not be stressed beyond their original allowable inventory stress level. All steel repairs shall be in accordance with the Steel Structures section of the Governing Specifications. All repairs to welds on steel members shall be in accordance with the AASHTO/AWS D1.5M/D1.5: current version, *Bridge Welding Code*.

2.7.3.1.1 Cracks

One method for preventing crack propagation is by drilling holes at the ends of the crack. Consideration shall also be given to filling the hole with a tightened high strength bolt to aid in arresting further propagation. Dye penetrant is used to locate and determine the extent of surface cracks. The center of the drilled hole should be positioned so that the end of the crack is located within the hole. If the crack is visible on both sides of the plate, the position of the outside diameter of the hole is at the end of crack that has propagated farthest. Dye penetrant is again used to ensure that the crack did not propagate through the drilled hole. The Federal Highway Administration has published guidelines on this procedure that are available at the Division of Highways.

Welding can be used to repair typical cracks in flanges and webs of beams or girders. Welding in connection with crack repair shall be done in accordance with AWS and the Governing Specifications. The weldability of the bridge material must be assessed prior to the repair procedure to insure a successful weld repair. See the section on fatigue to avoid use of fatigue-critical weld details.

Superficial nicks and gouges should be repaired by grinding rather than by welding repairs.

2.7.3.1.2 Painting

Repair work for corrosion may include painting of the structure. This consists of surface preparation, prime coating, and finish coating and shall be in accordance with the

Painting Steel Structures section of the Standard Specifications and Appendix D, Coatings.

The Designer is responsible for determining the presence or absence of lead based coatings by requesting that the Division of Highway's Materials Control, Soils and Testing Division conduct a field survey. If a lead based coating is present then the project plans shall contain a note as follows: "The contractor's attention is directed to the fact that the existing structure contains lead based paint coatings".

2.7.3.1.3 Fatigue

In zones of tension stress, when fatigue critical details exist, action must be taken to improve the expected fatigue life of the detail unless a cumulative damage fatigue analysis yields adequate life. The Designer should not use Category D, E or E' weld details for a repair or a new design. The fatigue life analysis shall be performed in accordance with the current version of the *AASHTO Guide Specifications for Fatigue Evaluation of Existing Steel Bridges.*

In designing a fatigue repair, an examination of the existing connections should be performed. The repair should be one that attempts to reduce the fatigue category of the existing connections. The Designer shall consult the Governing Specifications for common connection details and their fatigue category. Figures 2.7.3.1.3A and 2.7.3.1.3B illustrate two accepted fatigue repairs.

2.7.3.1.4 Section Loss

Cover plates are an effective means for restoring section loss in a member. The member must be analyzed to ensure its original capacity can be attained with the addition of cover plates. Details of repairs are largely up to the Designer's creativity. The Designer must consider the fatigue characteristics of the repairs they design. If excessive deterioration exists, then replacement of the member may be required.

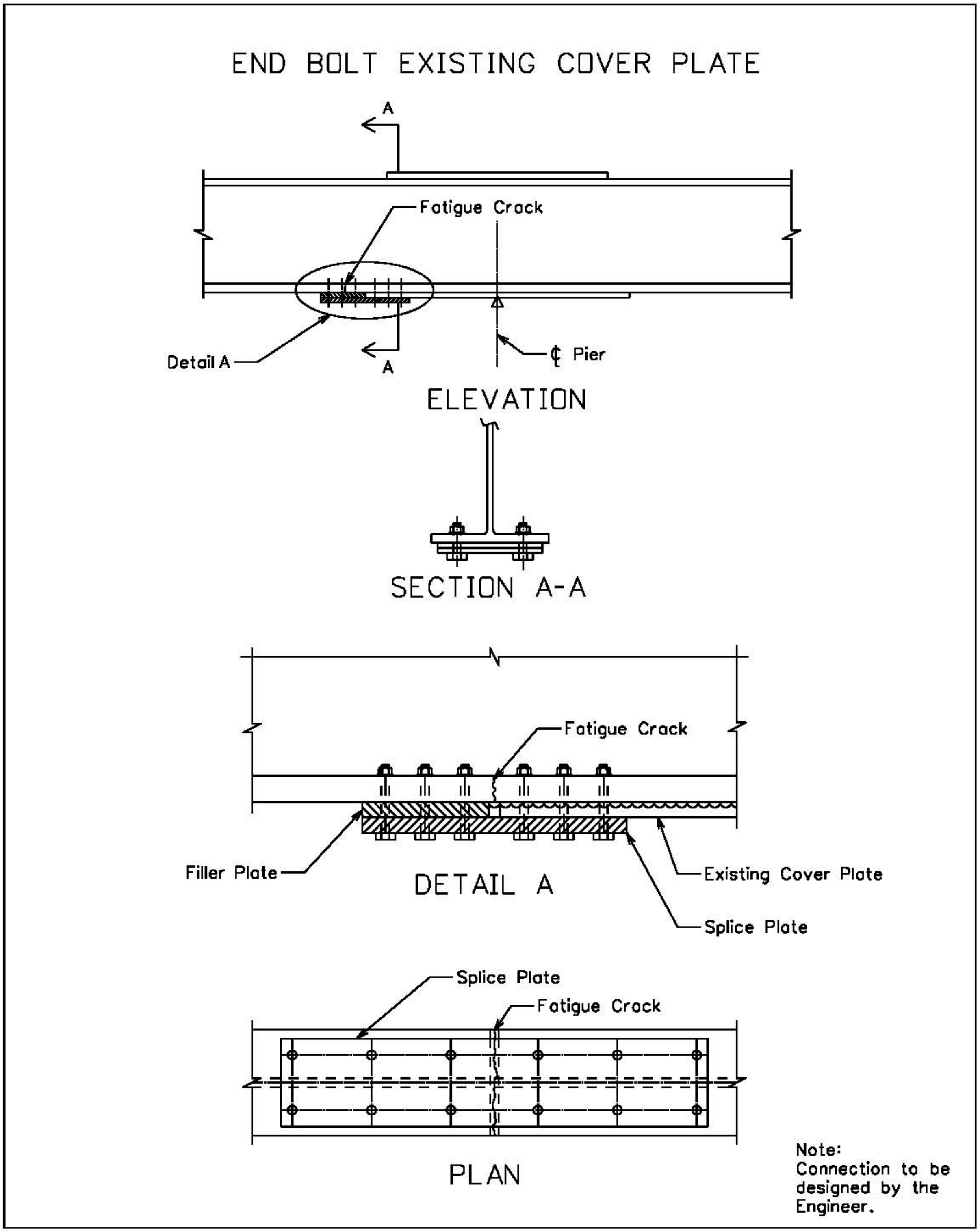


Figure 2.7.3.1.3A

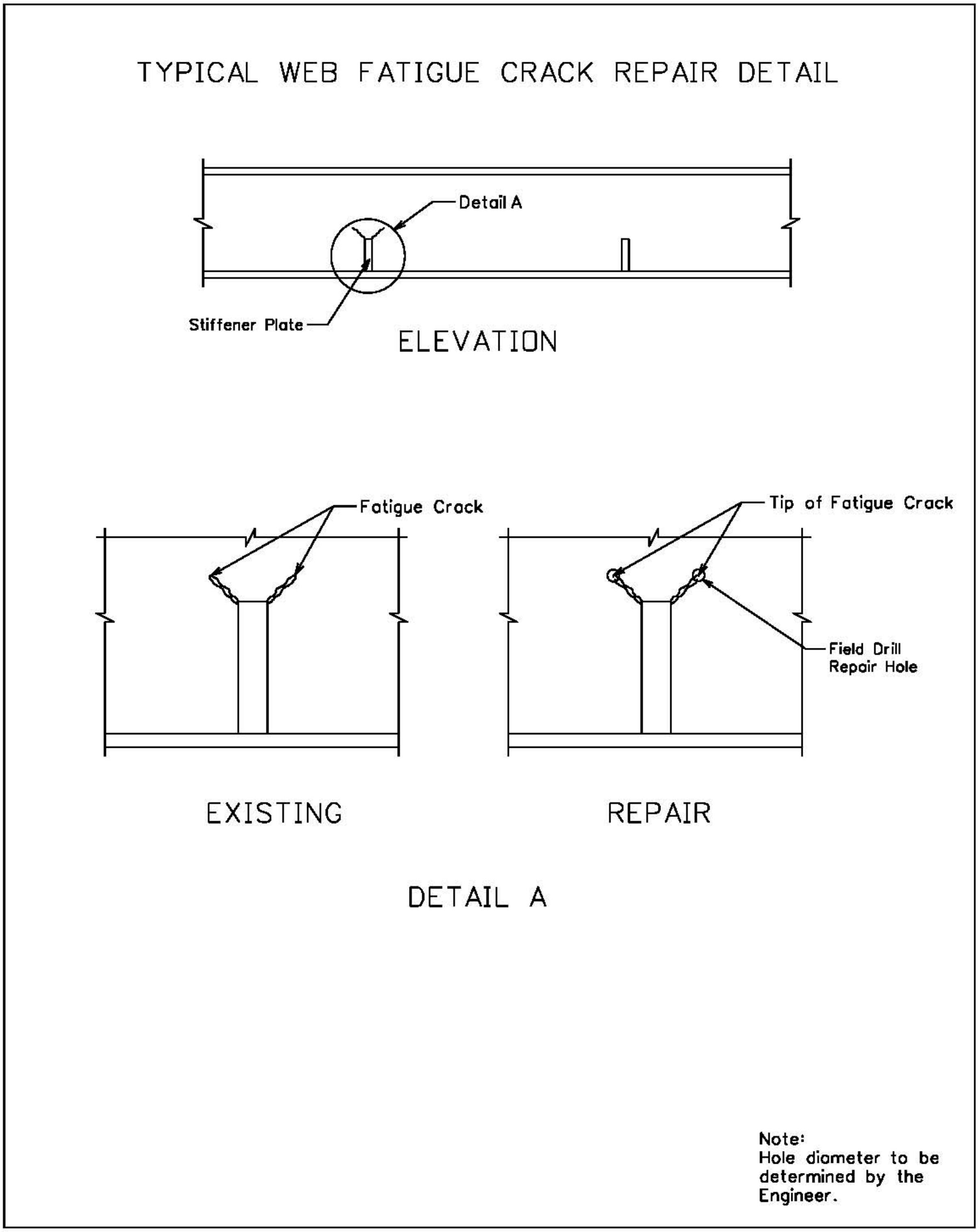


Figure 2.7.3.1.3B

2.7.3.2 Concrete

The intent of repairing concrete is to restore the structural integrity and function of the concrete. Typically, concrete repairs consist of removing deteriorated concrete and replacing it with cement mortar or another suitable material. Restoring proper cover, where existing cover is inadequate, is important in selecting repair materials. The following factors should be considered:

- structural compatibility of the material and its expected performance with the original construction,
- availability, cost and anticipated life, and
- ease of construction and availability of qualified contractors in the area.

Initially, all exterior concrete surfaces should be thoroughly examined by means of soundings with hammers to determine loose or defective areas that may exist beyond the visual assessment of deficiencies and deterioration. Defective areas should be removed to a depth necessary to eliminate any loose and disintegrated materials. All exposed reinforcement should be cleaned, care being taken to not damage the steel. Loose reinforcement should be tied back into place and, where necessary, concrete adjacent to loose bars shall be carefully undercut to a depth that permits a minimum of one inch of new concrete around the reinforcement bars. Sections with deteriorated bars should be re-evaluated and capacities restored, when necessary. The area of concrete removal should be large enough to allow for adequate bar splicing. The exposed area of concrete should be cleaned. Where concrete deterioration requires removal beyond half the depth of the member, consideration may be given to the replacement of the entire section in the deteriorated area.

A good bond between the repair material and existing concrete surfaces is essential in concrete repair. An epoxy-bonding coat applied just before the repair material can help to obtain a good bond. Dowel bars may be required in a section that is subjected to forces where the bond between the new concrete and the old section is not considered sufficient to transfer the loads. Dowels may consist of expansion anchors, grouted anchors, power-activated anchors, and epoxy and polymer grouts and resins. External or internal vibrators may be used for compaction. Proper curing is essential to ensure that excessive shrinkage will not occur.

Shotcrete can be used as a means for rebuilding an area where deteriorated concrete has been removed. Shotcrete applications are justified where large areas must be repaired and where conventional methods of forming and placing concrete are less suited to the damaged areas, such as vertical and overhead surfaces. Shotcrete application shall be in accordance with the Pneumatically Applied Mortar section of the Standard Specifications.

Cracks in concrete must be repaired to stop intrusion of water or chemicals into the concrete, and restore the uniform appearance of the concrete surface. Epoxy grouts are typically used for crack repair. This involves injection of low viscosity material under pressure with the intent to seal the crack and restore structural continuity. Where active cracking conditions exists, it must be dealt with by addressing the cause directly.

Grouting can also be used for the repair of concrete substructures submerged in water. This type of repair may necessitate the use of pile jackets or formwork.

All concrete repairs shall be in accordance with the Governing Specifications.

2.7.3.2.1 Concrete Decks

Most repairs needed in bridge decks are associated with increased traffic, heavier vehicles, deicing chemicals, and geometric deficiencies as a result of the initial construction. Common problems are cracking, spalling, chloride contamination, potholing, and delaminating. Cracking in the deck can be repaired as described in the previous section. Minor spalling, potholes, etc. may be temporarily repaired with patches. Patches cannot be considered a permanent solution. Eventually, a bridge deck becomes a composition of patches with no end to the repair process. As the patching process is repeated to repair more damaged areas, an overlay will be needed to serve as a wearing surface and a moisture barrier.

When repairs on a concrete slab become too costly, partial or complete replacement of the deck is needed. See Section 3.2 for design details for concrete decks.

See Appendix A for the Deck Removal-Grinding note to be included on the General Notes sheet for all projects requiring partial or complete deck removal on existing bridges.

2.7.3.2.2 Deck Overlays

When a specialized concrete overlay (SCO) is used on a deck greater than 7.0 IN thick, the deteriorated concrete shall be removed by rotomilling to 1.0 IN above the rebar followed by hydro-demolition. Conventional concrete removal, such as rotomilling and the use of pavement breakers shall not be utilized for slabs less than 7.0 IN thick. For slabs, 6.5 to 7.0 IN thick, special consideration must be given to methods of removal of the deteriorated concrete, such as hydro-demolition, so that damage of the remaining slab is minimized. A specialized concrete overlay will not be considered an acceptable method for deck retrofit for any bridge deck where the original slab thickness is less than 6.5 IN.

2.7.3.3 Additional Rehabilitation Issues

In past years, it was general practice in the steel bridge building industry to attach miscellaneous brackets, supports and details to the top flanges of stringers and floor beams by field welding. This work was not detailed on contract plans or steel fabrication drawings and was done to facilitate temporary support of various construction aids. The welding may have been performed under limited or no supervision, without proper preheat of the base material using electrodes of unknown quality and condition. Most of these welds were not removed prior to placing the deck.

The industry has since learned that these unauthorized welds are a potential source of fatigue cracking in the negative moment regions of the member flanges and should be removed during subsequent deck replacement. After removal, nondestructive testing is also appropriate to assure integrity of the member flange.

2.7.3.4 Timber

Timber members may experience deterioration from decay, insect attacks, and mechanical damage.

Surface treatments or coatings are applied to existing bridge members to protect the wood. This is most effective when applied before decay begins and is used to treat splits, delaminations, mechanical damage or areas that were field-fabricated during construction. Shallow penetration limits its effectiveness against established internal decay. Creosote is the preferred treatment. The wood surface should be thoroughly saturated with the treatment so that all cracks and crevices are coated. However, care must be exercised to prevent excessive amounts from spilling or running off the surface and contaminating water or soil. The effectiveness of surface treatments depends on the thoroughness of application, wood species, size, and moisture content at the time of treatment.

Mechanical repair methods use steel fasteners and additional wood or steel components to strengthen or reinforce members. These methods include splicing and stress laminating. Splicing is used to restore load transfer at a break, split, or other defect. Stress laminating may be used for the repair of nail-laminated decks.

Epoxy resins are used as a bonding agent in timber repairs. Epoxy seals the affected area, preventing water and other debris from entering. This should be limited to cosmetic repairs involving surface damage, not internal insect damage.

All timber repairs shall be in accordance with the Governing Specifications.

2.7.3.5 Deck Joints

The following sections describe rehabilitation techniques associated with commonly used types of expansion joints. It is the WVDOH's policy to eliminate deck joints where practical. When replacing an expansion joint, the installation procedures shall be in accordance with the Governing Specifications and the Manufacturer's instructions.

2.7.3.5.1 Open Joints

Finger joints are considered open joints. The major problems associated with finger joints are poor drainage, closed fingers, and loose attachments.

Improper drainage allows deicing chemicals, roadway grit, and gravel to collect on supporting beams and substructure units, causing accelerated rusting and concrete deterioration. Poor drainage can be corrected by first flushing the area to remove debris, then installing sheet metal deflectors or a neoprene trough to divert drainage and prevent the accumulation of debris. Future drainage problems can be prevented through frequent clearing of the drain troughs.

Finger joints that have become permanently closed can exert considerable forces on adjacent structural elements. Closed finger joints are a result of excessive movements of substructure units or insufficient allowances for roadway expansion. If roadway expansion is the cause of the joint closure, a pressure relief joint should be installed in the concrete approach pavement. When joints close due to excessive substructure movements, the unit that is causing the closure should be shifted to correct the problem. If the substructure unit is an abutment, the preferred solution, if practical, is to remove the joint and construct a semi-integral abutment. If the previously stated repairs are not economical, then the suggested means of relieving the pressure is to trim the expansion fingers or to remove and reinstall the entire joint system.

Structural components that have become loose, as a result of vehicular impact, can cause the joint to move in unanticipated ways and damage adjacent concrete. Excessive vertical movement may result in misalignment that can pose a roadway hazard. Finger bars that have broken loose at the welds should be repositioned and welded. Damaged curb plates, if still properly attached, should be straightened in place. Damaged concrete adjacent to the finger joint should be replaced.

2.7.3.5.2 Closed Joints

Elastomeric expansion devices, compression seals, and strip seals are considered closed joints. Each type of closed joints has specific problems associated with them.

Elastomeric expansion devices are a sealed, waterproof joint consisting of steel plates and angles molded into a neoprene covering. Common joint failure occurs in the form of leaking, delamination, loosened or damaged anchor bolts, and damage caused by snowplows during snow removal. An elastomeric joint that shows signs of leaking can be repaired by resealing the joint. Where severe leakage has occurred, the entire section should be replaced. Elastomeric joints that have become delaminated should be replaced. Proper anchorage can be achieved by replacing loose or damaged anchor bolts with new bolts. A section of an elastomeric device that has been damaged by snowplows shall be replaced with a new elastomeric section.

Compression seals are extruded neoprene shapes that are chemically bonded to the adjacent structures. One common failure of compression seals is the loss of bond between the joint material and the adjoining concrete or steel section. The neoprene can also become twisted if the concrete surrounding the joint armoring is not fully consolidated. An acceptable repair for these problems is a complete replacement of the compression seal with a two-part silicone sealant. However, this should only be performed if the concrete headers are found to be in satisfactory condition. If headers have failed, replace with an elastomeric expansion device. If it is practical, the desired repair for a compression seal is to replace the joint and convert the abutment into an integral or semi-integral abutment.

Strip seals consist of a heavy duty-neoprene gland, snaplocked into an extruded steel anchorage. Failures found in strip seals are similar to the ones associated with those of a compression seal; loss of anchorage and deformation of the neoprene gland. A common repair is to remove the damaged neoprene gland and spalling concrete, patch the concrete with an elastomeric concrete, then reinstall the neoprene gland after the concrete has cured. If it is practical, the desired repair for a strip seal is to replace the joint and convert the abutment into an integral or semi-integral abutment.

2.7.3.6 Bearings

The following section will briefly discuss problems common to all types of bearings. This applies to expansion, fixed, pot, sliding and elastomeric bearings. The accumulation of debris on bridge seats attracts and retains moisture. This, combined with deicing chemicals, will cause corrosion of any steel member; particularly components subjected to movement and large forces. Any repairs shall be in accordance with the Governing Specifications.

The decision to repair or replace should be based on the ability of the device to transfer vertical loads and to accommodate superstructure movement. Deficiencies that in most cases warrant repair include the following:

- light rust or surface scaling of non-contact surfaces,
- loss of lubrication,
- debris and dirt accumulation on the bearing seat,
- minor tilting and displacement of bearing components,
- rusted masonry and keeper plates, and
- missing nuts or deteriorated anchor bolts.

Bearings requiring replacement are ones that are severely deteriorated, suffered loss of function, and exhibit signs of imminent structural instability. The following can be used as a guideline in the choice of bearing replacement:

- the ability of the bearing to provide the same functions as the existing in terms of load transfer and movement,

- compatibility with the environment,
- dimensions of new bearing, particularly the height, and
- structural compatibility of the bearing with other bridge components.

2.7.3.7 Historical Structures

Historic structures that are scheduled for rehabilitation shall adhere to the United States Department of Interior's *Standards for the Treatment of Historic Properties*. These standards can be obtained from the WVDOH's Environmental Section. The Designer shall work closely with the WVDOH on historic rehabilitation projects.

2.8 BRIDGE PERMITS

The Designer shall contact the Engineering Division of the WVDOH at the span arrangement stage to determine the required permits based on anticipated construction methods. The Bridge Designer is responsible for preparing the required permit package. See Appendix B for permit checklists. The Project Manager submits the permit to the appropriate agency.

The Designer shall obtain confirmation from the Bridge Project Manager on whether a mussel survey, for freshwater or endangered mussels, should be performed in the project area.

2.8.1 Coast Guard

The U. S. Coast Guard (USCG) requires their prior approval for navigable stream crossings.

The Engineering Director is responsible for obtaining a permit from the Commandant, United States Coast Guard. The permit approves the location and plans for the construction or alteration of any bridge on the State Highway System over navigable streams. Alteration is taken to mean changes to the existing navigation clearances.

Navigation lights and vertical clearance gauges are conditions of the permit and are subject to Coast Guard approval. The Coast Guard, not the State, makes the determination of need for this permit. In general, permits are required throughout West Virginia for streams to the head of navigation and three miles further upstream.

The following is quoted from the *Coast Guard Bridge Permits* publication:

"Waterway Requiring Bridge Permits:

Coast Guard jurisdiction is limited to the construction or alteration of bridges and causeways over waterways that have been determined to be navigable waterways of the United States by the U. S. Coast Guard. Navigable waterways of the United States for bridge administrative purposes are: (1) All waters that (i) are used, or are susceptible for use, by themselves or in connection with other waters in highways for substantial interstate or foreign commerce, or (ii) a governmental or non-governmental body having expertise in waterway improvement determines that the waterway is capable of improvement at a reasonable cost to provide, by its self or in connection with other waters, highways for substantial interstate or foreign commerce; or (2) all waters subject to the ebb and flow or the tide; or (3) tributaries and embayments which are lateral extensions of navigable waterways from the confluence up to the upstream to the limit of ordinary high water (navigable-in-law).

For these reasons, anyone planning to construct a bridge or causeway over a waterway which might be considered navigable under the above criteria, should contact the…[Eighth Coast Guard District, Bridge Branch, 1222 Spruce Street, St. Louis, Missouri 63103-2398, Telephone No. (314) 539-3900, Ext. 2378 for assistance]. However, prospective bridge builders are under no obligation to seek out a determination from the Coast Guard unless the nature and character of the waterway belies any reasonable conclusion that the waterway is navigable; the burden, if any, rests with the Coast Guard to determine the facts and reach a determination on its own motion or in response to a complaint.

Advance Approval Category Waterways:

The commandant, U. S. Coast Guard, has given his advance approval to the location and plans of bridges to be constructed across certain minor waterways navigable-in-law but not actually navigated other than by logs, log rafts, rowboats, canoes and small motorboats. In such cases, the clearances provided for high water stages will be considered adequate to meet the reasonable needs of navigation. Persons planning to construct a new bridge or causeway or alter an existing bridge or causeway over a navigable waterway are urged to contact the Coast Guard. Any case of reasonable doubt will be resolved by the usual practice of notice or hearing prior to a specific approval of the location and plans for the proposed structure based upon findings made at the time and under the conditions then existing."

In early project development stages, the designer in consultation with the WVDOH is responsible for assessing the need for a Coast Guard permit. The Designer should initiate contact with the USCG at the earliest possible stage of project development, providing opportunity for Coast Guard involvement throughout the environmental review process in accordance with 23 CFR, Part 771. The environmental section should be consulted for coordination procedures.

2.8.2 U. S. Army Corps of Engineers

The U. S. Army Corps of Engineers (Corps), under the authority of Section 404 of the Federal Clean Water Act, requires a landowner to obtain a permit from the Corps prior to beginning any non-exempt activity involving the placement of dredged or fill material in waters of the United States, including wetlands. "Waters of the United States" includes lakes, rivers, streams, wetlands, and other aquatic sites.

Any activities that will result in the excavation, discharge or placement of dredged or fill material into waters of the United States, including wetlands, will require a section 404 permit.

Individual permits are issued to a single entity (individuals or companies) to authorize specific activities. Once the U. S. Army Corps of Engineers receives a complete permit application, a public notice is issued which describes the proposed project. The Corps evaluates all comments received and makes a final permit decision.

General permits are issued to the public-at-large to authorize specific activities that have minimal environmental impacts such as bank stabilization activities or construction of farm buildings. A general permit can be issued on a state, regional, or nationwide basis. Activities authorized by a general permit require less review than an individual permit would require. The WVDOH does not have any state or regional permits. Therefore, individual or nationwide permits must be used.

2.8.3 106 Process (Historic)

The Bridge Designer shall be responsible for discussing with the Project Manager to determine if the bridge is considered historic and if there are any special requirements to be included in the design. Having environmental clearance does not mean that there are no other considerations to include.

2.9 ALTERNATE BRIDGE DESIGN

On large, complex bridges, it is likely that limiting the design to one material type will unnecessarily limit the number and competitiveness of potential bidders. It is in these cases that alternate designs are economical in terms of the extra design cost and additional time. When alternate designs are required, it is desirable that one superstructure is to be designed with steel and one with concrete. Alternate designs utilizing the same materials, on occasion, can be possible. In certain cases, it may be appropriate to have different superstructure material types for main spans and approach spans.

The Director of Engineering Division will determine, on a case-by-case basis, when alternate designs are to be required. Both alternates shall have the same design life, take a similar amount of time to construct, and shall have similar serviceability.

2.10 RAILROAD CONSIDERATIONS

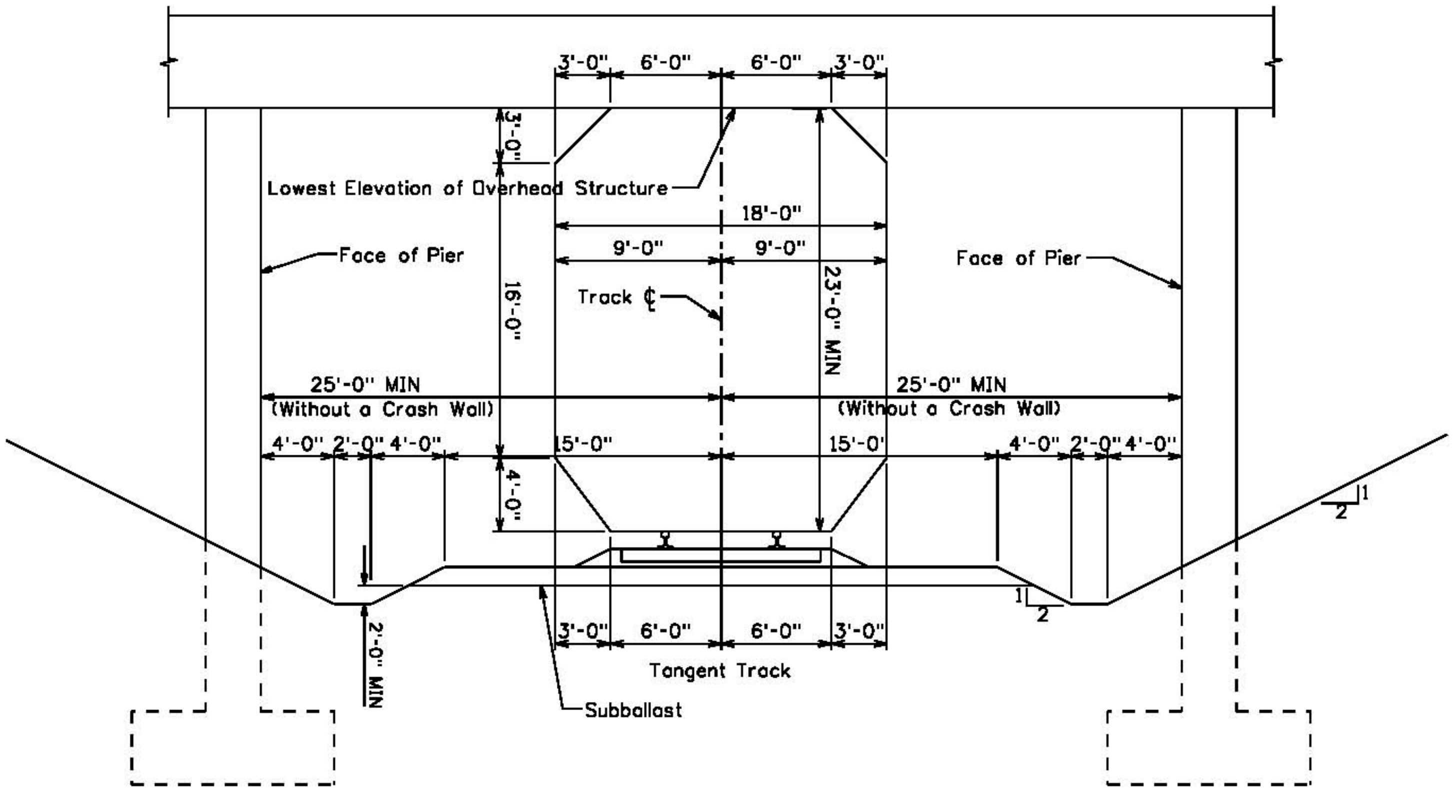
The preliminary plans for bridges to be constructed over railroads shall be submitted to the owner of the railroad by the Project Manager for review and approval. Bridge structures over railroads should generally be prepared following the basic geometric clearances shown in Figure 2.10. This figure represents the geometric requirements of the Norfolk Southern Corporation and CSX Transportation, Inc. and may vary when applied to other railroads.

2.10.1 Approval

The designer shall provide the clearance information for submission to the Railroad for their approval. The data shall identify the railroad division, the railroad valuation station at the centerline of bridge, the distance from the nearest milepost to centerline of bridge, the WVDOH crossing number and the state project number.

2.10.2 Crash Walls

To limit damage by the redirection and deflection of railroad equipment, piers supporting bridges over railroads and with a clear distance of less than 25 FT from the centerline of a railroad track shall be of heavy construction (defined below from *CSX Transportation Criteria for Overhead Bridges*) or shall be protected by a reinforced concrete crash wall. Crash walls for piers 12 to 25 FT clear from the centerline of track shall have a minimum height of 6 FT (10 FT for Norfolk Southern) above top of rail. Piers less than 12 FT clear



CLEARANCES REQUIRED FOR OVERHEAD STRUCTURES
TYPICAL ROADBED SECTION WITH STANDARD DITCHES

NOTE:
For multiple tracks, standard track centers is 15'-0".

From CSX Transportation Criteria for Overhead Bridges

Figure 2.10

from the centerline of track shall have a minimum crash wall height of 12 FT above the top of the rail.

The crash wall shall be at least 2.5 FT thick and at least 12 FT long. When two or more columns compose a pier, the crash wall shall connect the columns and extend at least one foot beyond the outermost column parallel to the track. The crash wall shall be anchored to the footings and columns, if applicable, with adequate reinforcing steel extending to at least 4 FT below the lowest surrounding grade.

> "Piers shall be considered of heavy construction if they have a cross-sectional area equal to or greater than that required for the crash wall and the larger of its dimensions is parallel to the track."

Consideration may be given to providing protection for bridge piers over 25 FT from the centerline of track, as conditions warrant. In making this determination, account shall be taken of such factors as horizontal and vertical alignment of the track, embankment height, and an assessment of the consequences of serious damage in the case of a collision.

2.10.3 Clearances

Minimum vertical clearance above the high rail shall be 23 FT. Rehabilitated or widened bridges will generally be allowed to maintain existing vertical clearance, but no less.

The preferred horizontal clearance from centerline of track to the face of the structural element is 25 FT. The absolute minimum on all new construction is 12 FT. Rehabilitation bridges will generally be allowed to maintain existing horizontal clearance, but no less.

See Figure 2.10 for an illustration of vertical and horizontal clearances.

The Railway-Highway Provisions of the Standard Specifications state there can be no work within railroad right-of-way without first obtaining authority from the Railroad's Chief Engineer. The designer should consider these restrictions in the design process to minimize encroachments.

2.10.4 Drainage

Proper drainage of railroad right-of-way must be considered during the layout and design of a railroad overpass.

Substructure units and embankment slopes shall not interfere with railroad ditches.

Deck drains shall be placed to prevent discharge onto the railroad right-of-way.

The Designer shall verify any additional drainage issues with the Bridge Project Manager.

2.11 BRIDGE DOCUMENT SUBMISSIONS

A detailed checklist for each submission is included in DD-202. The following sections give a brief description about each submission.

2.11.1 Design Report

A design report is a preliminary engineering study of proposed alignments for a project. The report will be subject to two scheduled reviews: Design Report Field Review and Design Report Office Review. Refer to DD-202 for more details for each submission requirements.

The Bridge Designer's tasks are to provide the necessary bridge information, cost estimates, and sketches for the report to be developed. This requires the Bridge Designer to look at existing conditions (geometry, major utilities, right-of-way, existing and/or adjacent structures, etc.), historical data, hydraulic opening, and proposed alignments to assist in the development of the report. The Bridge Designer should develop a cost and a plan and profile drawing for each alternate. These drawings are simple line drawings with minimal details (stationing, grades, vertical and horizontal curve data, etc.). The cost estimates shall be based on historic data for similar structures on a cost per square foot basis.

2.11.2 Pre-Span Arrangement Meeting

Prior to the submission of the Span Arrangement Report, the Bridge Designer shall meet with the Bridge Project Manager to discuss the feasible structural systems and span arrangements that should be included in the report. The purpose of this meeting will be to eliminate or add additional alternates for further consideration. This will save considerable time in the Span Arrangement submission stage. The Bridge Project Manager will make this final decision on what alternates should be studied.

At this meeting, the Bridge Designer should provide the following:

- Preliminary line and grade.
- Draft site plan for each recommended alternate showing both plan and profile views. Abutment location should be fairly accurate at this time. Piers should be located for each alternate being studied.
- Discussions on why alternates were chosen and others were not.

- Location of utilities, environmental concerns, roads, railroad tracks, etc. Include any obstacles that may influence recommendations.
- Superstructure types being considered.

At this time, no cost estimates, or girder analysis should be completed.

2.11.3 Span Arrangement Study

The Span Arrangement shall be submitted with the Preliminary Field Review Plans for the line and grade studies. The purpose of the Span Arrangement Study shall be to investigate all types of feasible structural systems, span arrangements, and establish all basic design and plan preparation parameters. Following the approval of the Span Arrangement Report and the Preliminary Field Review Plans, the Designer may obtain structural borings for the bridge. Approval of the Span Arrangement Report on any project shall not limit or preclude the taking of additional borings required by the Division of Highways following review of the TS&L nor does it constitute final acceptance of structure type or span arrangement. Please refer to Section 2.3, Geotechnical Investigations, concerning core borings and foundations.

The following list describes some of the information that should be included in the report. See DD-202 for a detailed list for each submission.

- Alignment, grades, typical sections, and superelevations used shall be documented in the Preliminary Field Review Plans.
- Consider all viable construction materials. Equal treatment between alternates is essential in ensuring competition and optimum cost-effectiveness. Uniformity of design criteria, material requirements, and appropriate unit costs shall be considered and documented.
- Hydraulic study (if crossing a waterway) justifying the proposed span arrangement, scour features, and grade shown in the Preliminary Field Review Plans.
- Discuss constructability, any special staged construction, clearance criteria (if crossing a road, railroad, or navigable waterway), freeboard (if crossing a waterway), and maintenance of traffic requirements.
- A description of the proposed superstructure depth and preliminary superstructure type utilized in the study, for each alternative span arrangement.
- All proposed computer software to be used during the "Combined TS&L" phase and final design phases of the bridge project.
- Deck drainage, superstructure joint, and bearing device requirements.
- Special environmental, aesthetic, and utility considerations.
- A description of the assumed foundation type used for cost estimates and geotechnical data.
- A preliminary total structure cost estimate for each span arrangement studied.

- Note proposed right-of-way limits, construction easements, and future maintenance operations.
- A detailed discussion documenting the Designer's recommended bridge layouts, to be advanced to the Combined TS&L phase, and the reasons for their selection. In most cases, the Bridge Designer is encouraged to recommend advancement of at least one concrete and one steel superstructure alternate. However, more than two alternates may be advanced.
- Unit prices shall be submitted for approval for all pay items that may be used during the plan development process.

The decision on what alternates are advanced is based on several factors:

- Cost of each alternate (cost differences of 10% or less at this stage are considered to be the same cost)
- Future maintenance costs
- Aesthetics
- Environmental concerns
- Constructability
- Redundancy
- Additional construction costs inherent of complex structures

All of these factors shall be taken into consideration, with present cost being the primary concern, to determine the recommended alternates. The ultimate decision is made by the Bridge Project Manager.

2.11.4 Type, Size and Location (TS&L)

Preliminary superstructure and substructure plans shall be submitted to the Engineering Division for approval of the recommended alternate prior to proceeding with final bridge design and the Final Detail Plan Submission.

Based on the approved Span Arrangement Study and approved Preliminary Field Review Plans, various alternates shall be studied to determine the most suitable structure. Consideration shall be given to both steel and concrete superstructures based on economics, serviceability, aesthetics, maintenance, and future use. Each alternate shall be developed equally. Recommendations should not be made until all information is complete for each alternate.

The specified grade(s) of steel used in the design will be as determined through performance requirements, availability and initial and long-term costs. Comparative studies will be completed during the TS&L Study. Results and recommendations will be provided in a clear and concise format, providing sufficient justification for the recommendations made.

At the time of selecting the preferred material type, life cycle costs may be considered. This consideration may include initial cost as well as expected maintenance cost and service life. For routine structures, this evaluation should be very informal and it will be the decision of the Bridge Designer to recommend the appropriate superstructure type based on experience and knowledge of the site.

It is recommended that two superstructure types be considered for most bridges in the TS&L stage. However, with the approval of the Bridge Project Manager, some smaller bridge projects may require the consideration of only one alternate.

The following list describes some of the information that should be included in the Combined TS&L Submission. See DD-202 for a detailed list.

- Key dimensions for superstructure and substructure. These dimensions should be very close to the final plans.
- Final grading.
- Deck drainage type.
- Design data - live load, future wearing surface, method of design, etc.
- Type of expansion joints (if applicable).
- Type of bearings and justification for their use.
- Detailed hydraulic study and design, including the scour analysis and design form DS-34 shall be submitted as follows
    - For District Design - Submit copy at TS&L stage to the District Bridge Engineer.
    - For Engineering Division In-House Design - The original copy of DS-34 will be submitted to the District Bridge Engineer.
    - For Consultant Design - The DS-34 form shall be submitted to the Engineering Division, Consultant Review Section.
- Discussion and full description of the various superstructure and substructure types that were considered. This shall include a discussion of any structure types that were not considered and the reason for elimination.
- Any proposed proprietary walls shall be investigated for applicability.
- A detailed total structure cost estimate for each appropriate superstructure/substructure combination to be developed in the Final Detailed Plan Submission.
- A detailed discussion of the advantages and disadvantages of the various structure types studied.
- The recommended superstructure and substructure to be developed in the Final Detailed Plan Submission. The ultimate decision shall be made by the Bridge Project Manager.
- A complete list of all project specific Special Provisions.
- Discussion of external stability for walls, embankment and temporary works.

2.11.4.1 Geotechnical Report

The Geotechnical Report shall be submitted with the TS&L Submission. It shall contain an evaluation of the recommended foundation type(s) (piling, spread footings, drilled caissons, etc.) and pile tips and bearing elevations. It shall also include the background information used, boring logs, core photos, subsurface information, test results, assumptions made, calculations and analysis, and a discussion on the foundations recommended for final design.

External influences (e.g., slope stability, settlement, mining and scour) must be addressed, and remedial measures must be recommended when required. Potential problems, which might require more information or further consideration before final design or during construction, should also be cited.

Bearing resistance for spread footings and drilled shafts shall be calculated using either the general bearing resistance equation or the lower bound equation presented in the governing specifications The selection of the general or lower bound equation shall be based on the Rock Mass Rating (RMR) either being less than or greater than 50, respectively. A resistance factor of 0.45 shall be used for both equations. Other bearing resistance equations may be allowed by the Geotechnical Engineer when a demonstrated need is presented to the division.
Lateral earth pressure coefficients shall be included the report and their application to fixed and movable abutments and wingwalls shall be discussed.

Settlement analyses shall consider preconsolidation pressure for cohesive soils and the report shall discuss whether the soil is considered overly or normally consolidated and why.

Where significant cut or fill slopes are associated with a bridge project, the geotechnical reports shall provide slope and benching recommendations.

2.11.5 Final Detail Plans

The Final Detail Plan Submission shall be submitted to the WVDOH for approval prior to submission of the PS&E Plans for comments and approval. At this stage, the plans and design shall be 100% complete. They should be ready to go to contract if no comments are given.

The following list describes some of the information that should be included with the plan submission. See DD-202 for a detailed list.

- Plans in 11 x 17 format
- Detailed cost estimate
- All applicable special provisions
- Contract completion time chart
- Reference to standard bridge and roadway drawings

- Copy of TS&L comments and actions taken
- Final Hydraulic Report
- Table of loads and factors to be used for bridge rating purposes
  - See DD-202 for bridge rating checklist

All plans shall be developed in accordance with Section 4 of this manual, General Plan Presentation.

2.11.6 Plans, Specifications and Estimates (PS&E)

The PS&E Submission is a project level submission, where the bridge plans are incorporated into the roadway plans.

This submission will be used to advertise the project for construction; it may be referred to as the PS&E Package. It shall include all revisions requested at the Final Plan Submission stage.

Plans include the following:

- Final plans in 11 x 17 format
- Standard Details (see Section 4)
- Contract Plans (see Section 4)
- Right-of-way Plans (see DD-301)
- See the following Design Directives for further information on plans
  - 701 – Plan Presentation
  - 702 – Title Sheet Signature Block
  - 703 – Plan Revision Blocks
  - 704 – General Notes
  - 705 – Quantities
- Full size mylar of title sheet, stamped by engineer registered to perform design work in West Virginia
- Electronic plans (if requested)

Specifications include the following:

- Standard Specifications (see Section 4)
- Supplemental Specifications (see Section 4)
- Special Provisions (see Section 4)

Estimates include the following:

- Contract Time Determination (see DD-803)
- Engineer's Cost Estimate (see DD-707)

A more detailed description of these components can be found in DD-706.

In order to assure consistent PS&E Packages, the Project Manager is responsible for the inclusion of the PS&E Checklist in the PS&E Package.

2.11.6.1 Establishing Contract Duration

The Designer is responsible for the development of a contract duration time bar chart. This chart is to be included in the submittal of a project for PS&E to determine the contract completion date. As a guide in this process, the WVDOH has published the *Guidelines for Production Rates and Chart for Contract Duration* (DD-803). This document is to be used as a starting point in determining contract duration, and should be augmented with outside sources of information, past experience with work of a similar nature, and good engineering judgment.

2.11.6.2 Engineer's Cost Estimate

The Engineer's Cost Estimate shall be an accurate reflection of the anticipated costs of the various items of work that are contained in the construction project. It is the responsibility of the Designer to provide this with the PS&E Package. Design Directive 707 details the requirements for the Engineer's Cost Estimate. In addition, the WVDOH annually compiles a book of Average Unit Bid Prices for the previous year's construction projects. This publication can be used to begin the estimating process for any individual items of work that are to be utilized on a project.

It is advisable to consult past projects of a similar nature and scope near the project that is being estimated to arrive at realistic cost data.

2.11.7 Tracings

This submission includes the reproducible set of tracings, design calculations and electronic plans, if requested.