SECTION 1 - INTRODUCTION

1.1 POLICY

1.1.1 Scope

This Bridge Design Manual will serve as a guide to the Designer in order to provide consistency in bridge designs throughout the state and to aid new designers and consultants on the policy, standards, and preferences of the West Virginia Division of Highways (WVDOH). The *AASHTO* (American Association of State Highway and Transportation Officials) *LRFD* (Load and Resistance Factor Design) *Bridge Design Specifications* will continue to be the basis for all highway bridges designed for the WVDOH. It is essential that designers maintain the needed flexibility to promote economical and creative designs. Therefore, exceptions based on sound engineering and practicality of construction will be evaluated. The benefits of this Manual will be the standardization of: the structure design process, common details, and the layout of the contract plans. In addition, it will provide minimum design standards for structures in West Virginia and provide interpretation and consistency in the application of the AASHTO Specifications. Finally, this Manual will replace the system of Structural Directives by incorporating them into the various sections of this manual. This manual may be found on the WVDOH's Engineering Publications and Manuals website at **http://www.transportation.wv.gov/highways/engineering/Pages/publications.aspx.**

Any questions, comments or suggestions are welcomed and should be addressed to:

Director, Engineering Division
West Virginia Division of Highways
1900 Kanawha Blvd., East
Building 5, Room 317
Charleston, West Virginia 25305-0430

1.1.2 Limitations

Due to the nature of this manual, it is not intended to be a design specification, providing all the information necessary to design a bridge or other structure in West Virginia. Rather, it is intended that this manual will: standardize the design process, provide information on required contents of contract drawings, and provide typical details. Even though this Manual was developed as a guide, it is expected that deviations to this Manual, the AASHTO Specifications and the WVDOH Design Directives (DD) be properly documented and submitted to the WVDOH Project Manager prior to proceeding with the plan development.

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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 Highway Drainage

[This Section Has Been Combined with Section 2.1.7]

2.1.6 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.

2.1.7 Highway Drainage, Hydrology and Hydraulics

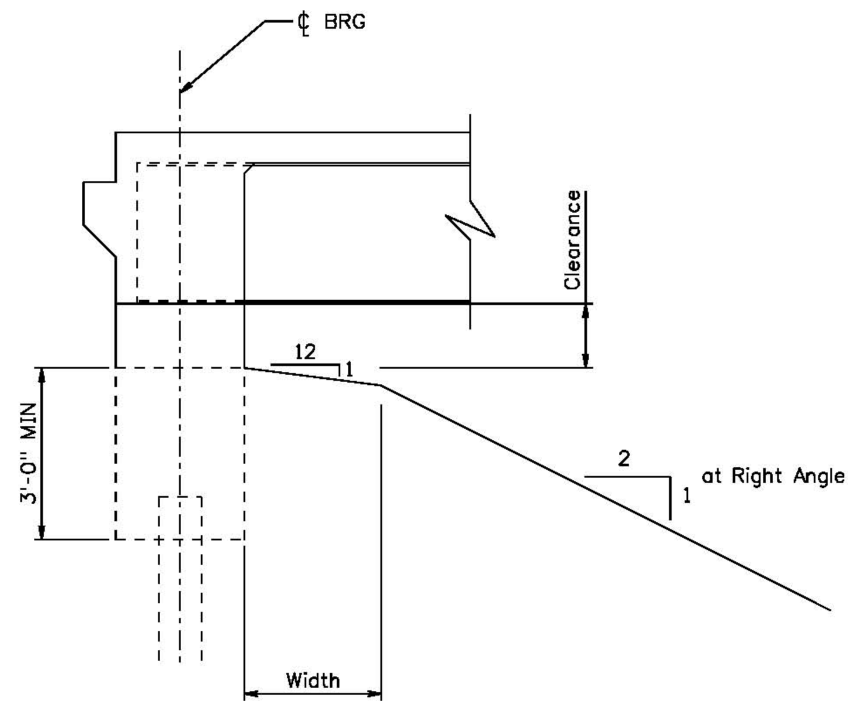
The WVDOH has developed a comprehensive Drainage Manual that shall be utilized in establishing design frequencies for highway drainage, hydrology and hydraulics on new and replacement structures. See also Design Directives Section 501 and AASHTO LRFD Specifications Section 2.6. A scour analysis shall 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. However, if the berm width is greater than 10 FT a minimum 3 FT clearance should be used to provide clearance for ventilation, vegetation 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 analysis is performed.



BERM LAYOUT SECTION

Figure 2.2.1A

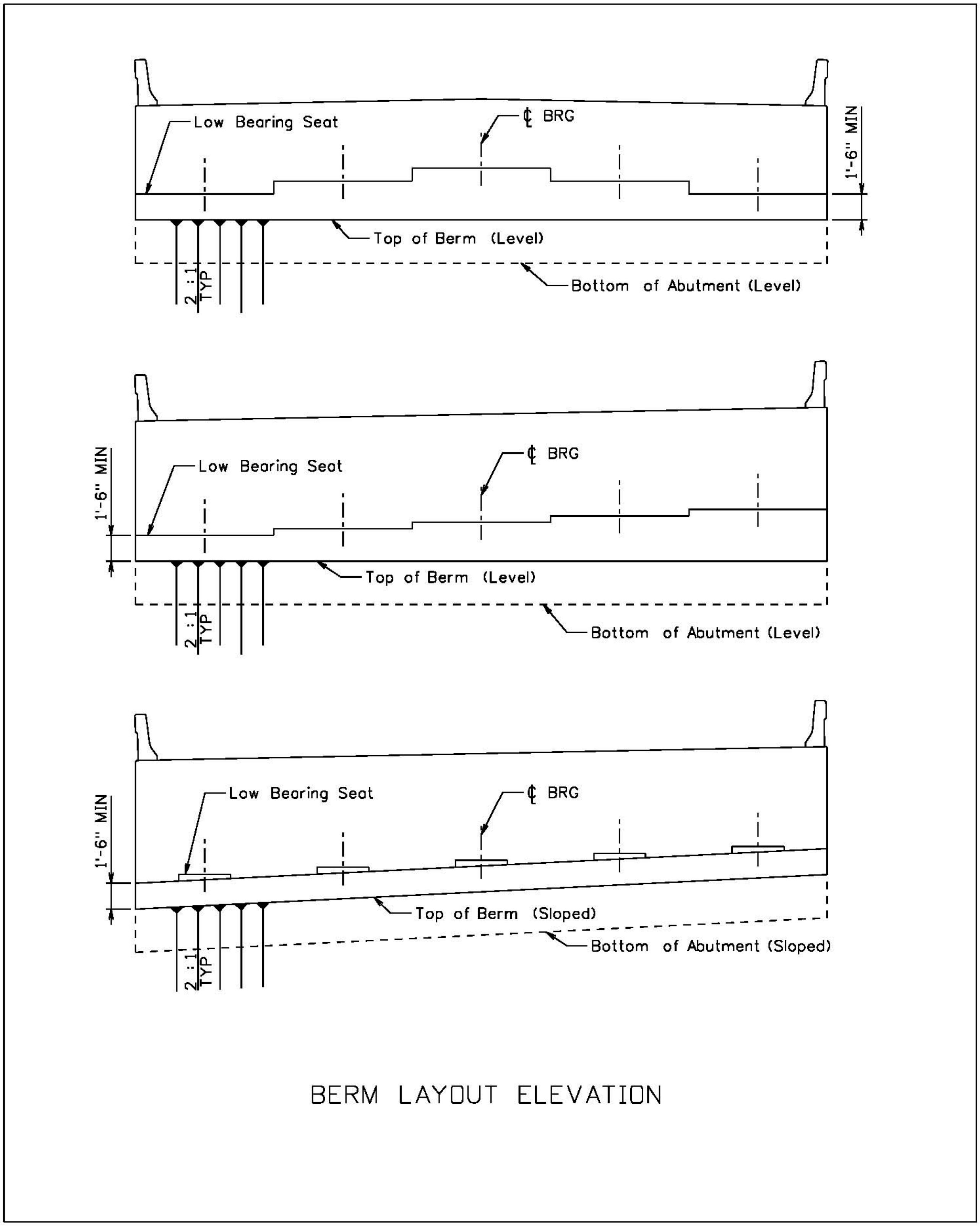

Low Bearing Seat
℄ BRG
1'-6" MIN
Top of Berm (Level)
Bottom of Abutment (Level)
2 : 1
TYP
Low Bearing Seat
℄ BRG
1'-6" MIN
Top of Berm (Level)
Bottom of Abutment (Level)
2 : 1
TYP
Low Bearing Seat
℄ BRG
1'-6" MIN
Top of Berm (Sloped)
Bottom of Abutment (Sloped)
2 : 1
TYP
BERM LAYOUT ELEVATION

Figure 2.2.1B

2.2.2 Bridge Length

The length of the bridge is determined by the attributes 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. The Designer should 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, ideally is 2 FT, with assurance that the bridge bearings are above the design discharge elevation.

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.

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

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.

Table 2.2.2.2

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 roadways and roadway structures. 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 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

SECTION 3 - DESIGN

3.1 DESIGN CRITERIA

3.1.1 Working Stress Design

Effective July 1, 1998, the Working Stress Design Method is no longer approved for the design of structures.

3.1.2 Strength Design (LFD)

Effective July 1, 1998, the Strength Design (LFD) Method is no longer approved for the design of structures, except for curved girders (see Section 3.3.10) and load rating (see Section 3.15), without the approval of the Director of the Engineering Division.

3.1.3 Load and Resistance Factor Design (LRFD)

All structure designs started after July 1, 1998, shall be in accordance with the latest edition (including interim specifications) of the AASHTO Load and Resistance Factor Design (LRFD) Specifications, hereafter referred to as the Governing Specifications or AASHTO.

3.1.4 Loads and Load Factors

3.1.4.1 Loads

The Designer must consider all loads that are expected to be applied to the structure. These loads shall include but not be limited to permanent loads, live loads, water loads, construction loads, wind loads, ice loads, earthquake effects, earth pressure, vehicular collision force, force effects due to superimposed deformations, friction forces and vessel collision forces. These loads shall be in accordance with Section 3 of the Governing Specifications, unless specified otherwise within this document.

The Owner’s decisions on various design criteria are listed herein.

3.1.4.1.1 Permanent Loads

Permanent loads shall include dead loads due to the weight of all structural components including future wearing surface, earth surcharge (as applicable) and horizontal earth pressure.

The Designer shall use a load of 15 PSF for permanent deck forms. When girder or beam spacing 14 feet or greater are utilized, the designer shall determine if the 15 PSF for permanent deck forms needs to be increased. All structures shall be designed for a future wearing surface of 25 PSF. Unless a more refined analysis is performed to calculate active earth pressure, the Designer shall use a minimum of 40 PCF for equivalent fluid pressure (see AASHTO 3.11.5).

3.1.4.1.2 Live Loads

All structures shall be designed for the HL-93 live load. Fatigue load frequency, $ADTT_{SL}$ (number of trucks per day in one direction in a single lane over the design life-75 years), shall be provided to the Designer by the Bridge Project Manager. Otherwise, a factor, provided by the Bridge Project Manager, shall be used to reduce the ADTT (number of trucks per day in one direction averaged over the design life-75 years) to a single lane.

The dynamic load allowance may be reduced for components other than joints, if justified by sufficient evidence, in accordance with the provisions of AASHTO 4.7.2.1, Vehicle-Induced Vibrations). Approval by the WVDOH is required. The dynamic load allowance can be reduced by 50% for timber bridges and wood components of bridges.

3.1.4.1.3 Vehicular Collision Force

Abutments and piers located within a distance of 30.0 FT to the edge of the roadway shall be investigated for collision in accordance with the Governing Specifications (see AASHTO 3.6.5).

When corrugated stay-in-place forms are used, the design depth is taken as the minimum concrete thickness. Fill corrugations with concrete. The use of foam in the corrugations of stay-in-place formwork is prohibited. Deck forms shall be mechanically tied at common edges and fastened to their support. No welding of steel formwork is permitted. Steel formwork shall not be considered composite with the concrete slab.

3.2.1.4 Deck Protection Criteria

All reinforcing in the slab, barriers, medians, curbs and sidewalks shall be epoxy coated, except when alternate protection systems are approved by the Director of Engineering Division.

A dual protection deck system shall be provided for all concrete bridge decks on projects meeting either of the following criteria:

- Design ADT greater than 3500 vehicles per day (VPD)
- National Highway System (NHS) bridge

The dual protection shall be obtained by utilizing a Class H full depth concrete deck on all bridges with a maximum span length less than or equal to 350 FT.

All bridges with spans greater than 350 FT shall utilize a deck system with a specialized concrete overlay in combination with a Class K concrete deck. The overlay is placed after most of the dead load deflections have taken place, thus providing better control over the final elevation of the concrete deck.

To provide necessary information to field personnel in constructing specialized concrete decks and to help prevent rideability problems, Bridge Designers are required to:

- Provide cambers and deflections for stringers and floorbeams in the contract documents.
- Place an overlay on the deck whereby the overlay thickness is part of the 3.0 IN minimum clearance over the reinforcing steel bars.

3.2.2 **Barriers**

All new or replacement bridge barriers shall meet or exceed the following criteria:

- TL-3, when any of the following conditions apply:
  - National Highway System (NHS) Bridge
  - Design speed greater than 45 MPH
  - Design ADT greater than 3500 VPD
  - Deck type is concrete slab on girders
- TL-2, for all other bridges

   - Design speed must be less than 45 MPH to use a TL-2 barrier
- TL-1, where there is an exceptionally low volume of traffic on a 12 FT wide one lane bridge an exception for use of a TL-1 barrier may be considered if all of the criteria listed in DD-601, *"Conditions for one lane 12' clear bridge widths on new construction of new roads"* has been met.

The 32 IN Type F barrier is the standard barrier for all new and replacement projects, utilizing a TL-3 barrier. The Designer should note that the 32 IN Type F barrier meets TL-4 requirements. As with all railings, the attachment and supporting elements shall be designed to exceed the strength capacity of the barrier, per AASHTO Section 13. The 42 IN barrier may be specified for special projects based on geometric constraints. If there is a bicycle path adjacent to the barrier, the overall barrier height shall be 54 IN (including railing). Details for these barriers can be obtained from the WVDOH.

Sidewalk barriers shall be designed in accordance with AASHTO Section 13, Railings and Section 2.3.2.2.2. Sidewalk barriers subject to vehicular collision shall meet crash test requirements (AASHTO 13.11.1).

The barrier is constructed without vertical construction joints but is vertically scored for control joints. Longitudinal reinforcement shall be continuous.

The Type F barrier transition and guardrail attachment details can be obtained from the WVDOH. This transition shall occur outside the limits of the bridge, typically on the wingwalls or approach slabs.

3.2.2.1 Continuous Barriers for Deflection Control of Bridges

Generally, for short to medium span bridges, the AASHTO suggested limits for live load deflection may not govern the design of the main structural members. However, for medium to long span bridges and bridges with HPS 70W steel girders, serviceability criteria, such as live load deflection, become increasingly significant when proportioning the main members.

These provisions are also applicable to bridges designed in accordance with LFD. The following live load provisions will supersede the live load provisions of Article 2.5.2.6.2 when designing bridges in accordance with the AASHTO Standard Specifications for Highway Bridges:

- Continuous composite barriers and other structural appurtenances shall be used in the service and fatigue limit states. They shall not be utilized for other load cases without the approval of the Director of Engineering Division.

- To ensure satisfactory performance for strength and serviceably criteria, deflection control of bridges will be evaluated during design in accordance with AASHTO 2.5.2.6.2. The principles suggested by AASHTO 2.5.2.6.2 for deflection control and evaluation will be implemented in the design of bridges. Particular emphasis is placed on considering the entire bridge cross-section, including the entire width of the roadway and the structurally continuous portions of railings, sidewalks and median barriers, as effective for stiffness of compositely designed structures.

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Lumber size shall be selected based upon available sizes. Structural calculations shall be based upon available sizes. Structural calculations shall be based on actual dimensions rather than nominal dimensions.

3.6 BEARINGS

Bearing devices are mechanical systems that transmit loads from the superstructure to the substructure. Also, bearing devices provide for movement due to thermal expansion and contraction as well as rotational movement associated with the deflection of primary members. There are two principal types of bearings: fixed and expansion. Fixed bearings only allow rotation while expansion bearings permit both rotation and translation. All bridge bearing designs shall be in accordance with the Governing Specifications.

The applicability of certain types of bearings will vary depending on the loads and movement the bearing is required to sustain. Elastomeric bearings are preferred for most span arrangements. Polytetrafluorethylene (PTFE or Teflon) expansion bearing assemblies or pot bearings may be used when span lengths, curvature, or load limits for the standard elastomeric pads are exceeded. Elastomeric bearing pads shall be designed in accordance with the Governing Specifications using an elastomer with a hardness of 50-60 Durometers: “Method A” will be used for the design of unreinforced pads and “Method B” will be used for the design of steel reinforced pads.

Concrete surfaces in contact with the bearings shall be adequately reinforced to prevent bursting, splitting and/or spalling. This also applies to any jacking pockets or jacking locations provided for the future replacement of bearings.

Where the potential for slip exists between an elastomeric bearing pad and the beam seat, use epoxy grit to increase the coefficient of friction between the surfaces in contact.

Any components to be welded to the superstructure steel, such as sole plates, shall be painted as superstructure steel. Plates, fasteners or other components fabricated as part of, and permanently attached to elastomeric bearings may be painted.

Steel components of bearing devices shall be galvanized/metalized except as noted. These components shall include, but not limited to, masonry plates, rockers, sliding bearing plates, pins, bolts, nuts, washers, anchor bolts, nuts and washers. Galvanizing shall be hot dipped galvanizing in accordance with AASHTO.

Proper consideration shall be given to those components that have finished surfaces such as sliding bearing surfaces, finished surfaces of pins, and pin holes where galvanizing may not be permissible. Plates receiving Teflon pads or stainless steel sheets shall not be galvanized. The plates shall be SSPC-SP-6, commercial blast cleaned, and except for areas with special facings, shall be painted in accordance with the Specifications.

Weathering steel may be used for bearing devices. There are no known issues of having galvanized parts in contact with weathering steel.

Slotted holes are not permitted on fixed bearings.

All bridge bearings shall be accessible for inspection and maintenance with the exception of integral abutment bearings. The bearings shall also be replaceable without damage to the structure and without removing anchorages permanently attached to the substructure.

3.6.1 Bearing Design Criteria

Combinations of load, rotation and translation anticipated during construction shall be incorporated into the design of the bearings with allowance for construction tolerances and variation of temperature at installation. It is possible that the rotation and translation of the bearings may be significant during construction and may not be fully relieved, resulting in "locked-in stresses" in the bearing. If not sufficiently accounted for in design, these effects from construction could potentially cause an overstress under normal service conditions and/or adversely affect service life of the bearing. The Designer shall evaluate construction loading and movement in the design of the bearings and incorporate the most cost-effective of the following alternatives to control or relieve stress in the bearings from construction:

- Prior to allowing traffic on the newly constructed bridge, jack the bearing assemblies to relieve possible stresses that may have occurred during construction. This excludes bearings at integral supports. For concrete beam structures made continuous for live load, jack bearing assemblies prior to casting the continuity joint.
- Design the bearings for additional movement/rotation during construction that includes sufficient tolerance for; temperature variation at installation (from assumed ambient temperature), anticipated rotations and out of level support surfaces at the bearing seats.
- Prescribe the installation temperature for the bearings and require beam seats to be level or within defined dimensions. These requirements shall be incorporated into the design of the bearings, specified in the construction documents and verified during construction.

Elastomeric bearings for integral abutments must be designed to support non-composite dead load reactions and beam rotations. Thermal forces are not considered since the time between beam placement and final closure pour is assumed to be small. Reactions and rotations shall be based on actual span configuration. No further design cases are required. All superimposed dead loads and live loads at the final configuration are supported by the closure pour. The minimum pad thickness is ½ IN.

3.14.2.2 Joint Type Between Approach Slab and Approach Pavement or Bridge Transition Pavement

For integral bridges, a Type H joint (Standard Detail Sheet PVT2) is required to accommodate the thermal movement when using flexible approach pavement. Rigid bridge transition pavement requires a Type B joint (Standard Sheet PVT1) between the approach slab and the bridge transition pavement for movements up to 0.25 IN and a Type J joint (Standard Sheet PVT5) for movements greater than 0.25 IN.

Bridges with expansion joints require a Type H joint (Standard Detail Sheet PVT2) when the approach pavement is flexible and a Type A joint (Standard Sheet PVT1) when the bridge transition pavement is rigid.

3.14.2.3 Detailing

The approach slab detail sheet(s) included in the plans shall be an all-inclusive sheet(s) with pay items, quantities, and bar schedule. The items on this sheet are considered roadway pay items and are included in the roadway summary and estimate of quantities.

3.15 LOAD RATING OF NEW BRIDGE DESIGN

Load and Resistance Factor Rating (LRFR) is consistent with the LRFD Specifications in using a reliability-based limit states philosophy and extends the provisions of the LRFD Specifications to the areas of inspection, load rating, posting and permit rules, fatigue evaluation, and load testing of existing bridges. The LRFR methodology has been developed to provide uniform reliability in bridge load ratings.

Load rating analysis shall be performed for all new or replacement bridges, including Value Engineering or Value Engineering Change Proposals submitted by the Contractor, using the LRFR Method found in the current edition of the AASHTO Manual for Bridge Evaluation (MBE). This document provides guidance to load rating engineers for performing and submitting load rating calculations and serves as a supplement to the MBE to describe WVDOT specific load rating requirements.

Each bridge shall be load rated at inventory and operating levels for AASHTO’s HL93 loading as presented in the Governing Specifications on all routes. In addition, an analysis shall be completed for each of the five West Virginia Legal Loads (H, Type 3, WV-SU4, HS and 3S2) on all routes. Bridges on a Coal Resource Transportation System (CRTS) Route shall be load rated for four additional trucks (WV-SU40, WV-SU45, WV-3S55, and WV-3S60). The axle configurations and loads for the WV Legal Trucks and the CRTS Trucks are shown in Figure 3.15.

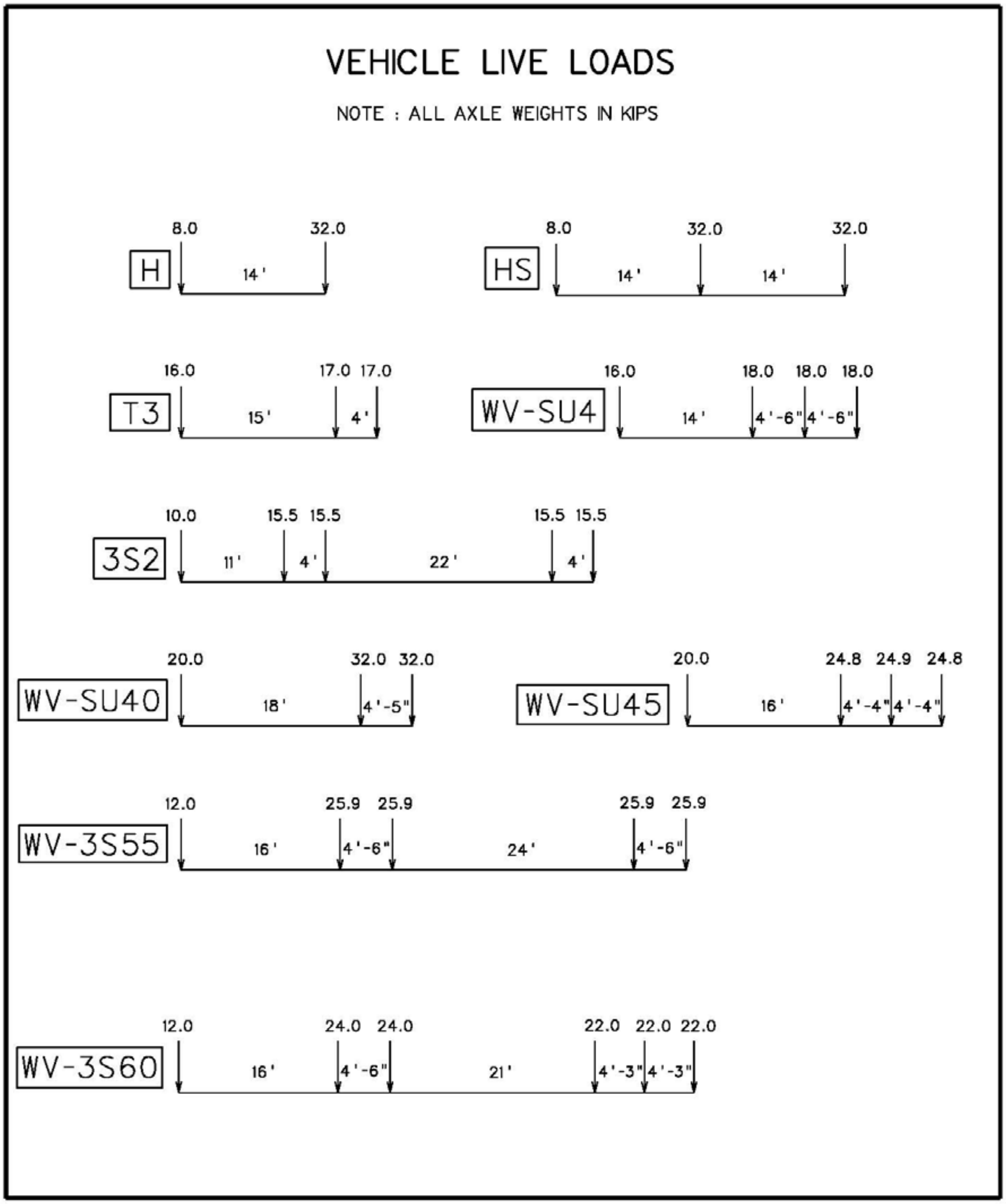
VEHICLE LIVE LOADS
NOTE : ALL AXLE WEIGHTS IN KIPS
H
8.0
32.0
14'
HS
8.0
32.0
32.0
14'
14'
T3
16.0
17.0 17.0
15'
4'
WV-SU4
16.0
18.0 18.0 18.0
14'
4'-6"
4'-6"
3S2
10.0
15.5 15.5
15.5 15.5
11'
4'
22'
4'
WV-SU40
20.0
32.0 32.0
18'
4'-5"
WV-SU45
20.0
24.8 24.9 24.8
16'
4'-4"
4'-4"
WV-3S55
12.0
25.9 25.9
25.9 25.9
16'
4'-6"
24'
4'-6"
WV-3S60
12.0
24.0 24.0
22.0 22.0 22.0
16'
4'-6"
21'
4'-3"
4'-3"

Figure 3.15

The bridge load rating analysis using the LRFR Method shall be performed concurrent with the beam/girder final design to assure proper design and adequate rating. The target inventory ratings for new or replacement bridge designs are shown in Table 3.15.

Route	HL93 (RF)	H (Tons)	Type 3 (Tons)	WV SU4 (Tons)	HS (Tons)	3S2 (Tons)	SU40* (Tons)	SU45* (Tons)	3S55* (Tons)	3S60* (Tons)
Interstate	1.00	20	27	29	37	40	-	-	-	-
65,000 lb	1.00	22	33	36	36	36	-	-	-	-
80,000 lb	1.00	22	33	39	41	44	-	-	-	-
CRTS	1.00	22	33	39	41	44	42	48	58	63

*Required for CRTS Routes Only

Table 3.15 – Target Inventory Ratings

If the rating of bridges designed using the LRFD Specifications is less than the target value, and the design is found to be adequate, the Bridge Project Manager in coordination with the evaluation section shall be contacted immediately to determine what actions are to be taken before proceeding further with the final design and detailing.

The Designer shall state in the plans when redistribution of negative moments is utilized for use in the permit rating of the bridge (see AASHTO 4.6.4).

A request for load rating shall be submitted to Maintenance Division (OM) by the Bridge Project Manager during the load rating submission. The request shall contain the following information:

- Load rating sheets containing tabulated section properties, live load distribution factors, dead load moments and shears, and live load moments and shears at critical locations in each span and at all supports
- Superstructure framing plan, typical cross section, girder elevation, and bridge general notes sheets
- The PS&E date of the project

If requested, the Designer shall also be required to submit to OM original rating computations included with the design calculations and shall clearly identify or include the following information:

- Design specifications
- Design live load
- Member capacities
- Method of analysis – line girder, grid, or finite element
- Method used for calculation of live load distribution factors
- Live load distribution factors
- Table of applicable load factors
- Controlling limit states
- Inventory and Operating Ratings for all required loadings for consultant designed bridges if required by project scope
- Relevant computer input and output information for consultant designed bridges if required by project scope

3.15.1 Rating Computations

The load rating shall be computed using the following general rating equation (see MBE 6A.4.2.1):

$$RF = \frac{C - (\gamma DC)(DC) - (\gamma DW)(DW) \pm (\gamma p)(P)}{(\gamma LL)(LL + IM)}$$

RF = Rating Factor
C = Capacity
DC = Dead load effect due to structural components and attachments
DW = Dead load effects due to wearing surface and utilities
P = Permanent loads other than dead loads (secondary prestressing effects, etc.)
LL = Live load effect of the Rating Vehicle
IM = Dynamic load allowance
γ DC = LRFD load factor for structural components and attachments
γ DW = LRFD load factor for wearing surfaces and utilities
γ p = LRFD load factor for permanent loads other than dead loads = 1.0
γ LL = Evaluation live load factor for the Rating Vehicle

Load factors shall be determined from MBE Table 6A.4.2.2-1

3.15.1.1 For Strength Limit States:

$C = \phi c \phi s \phi Rn$

Where the following lower limit shall apply:

$\phi c\ \phi s \geq 0.85$

3.15.1.2 For All Non-Strength Limit States:

C = f_R

ϕc = Condition Factor

ϕs = System Factor

ϕ = AASHTO LRFD Resistance Factor

Rn = Nominal member resistance (as built or as inspected)

f_R = Allowable stress specified in the LRFD code

3.15.2 LRFR Limit States for Evaluation

Strength limit state is used for checking the ultimate capacity of structural members and is the primary limit state utilized for determining posting needs. Service and fatigue limit states are utilized to limit stresses, deformations, and cracking under regular service conditions. In LRFR, Service and Fatigue limit state checks are optional in the sense that a posting or permit decision does not have to be dictated by the result. These serviceability checks provide valuable information for the engineer to use in the decision process. LRFR limit states for evaluation are shown in Table 3.15.2 below. Evaluation at the strength limit state is the only required check during the LRFR analysis on all new or replacement bridges. Evaluation at the service and fatigue limit states will not be required unless specified as part of the initial scope of work.

Bridge Type	Limit State	Design	Legal
		HL93	H, Type3, WV SU4, HS, 3S2, CRTS, Lane Load Models
Steel	Strength I	**x**	**x**
	Strength II		
	Service II	**xx**	**xx**
Reinforced Concrete	Strength I	**x**	**x**
	Strength II		
	Service I		
Prestressed Concrete (non-segmental)	Strength I	**x**	**x**
	Strength II		
	Service III	**xx**	
Timber	Strength I	**x**	**x**
	Strength II		

X – Required evaluation on all new or replacement bridges
XX – Optional evaluation required only if specified during initial scope of work meeting

Table 3.15.2

For non-segmental prestressed concrete bridges, LRFR provides a limit state check for cracking of concrete (SERVICE III) by limiting concrete tensile stresses under service loads. Service III need not be checked for design load Operating Ratings as it is a design level check.

Service I and Service III limit states are mandatory for load rating of segmental concrete box girder bridges (see MBE 6A.5.14).

A new SERVICE I load combination for reinforced concrete components and prestressed concrete components has been introduced in LRFR to check for possible inelastic deformations in the reinforcing steel during heavy permit load crossings (see MBE 6A.5.4.2.2.2). This check shall be applied to permit load checks and sets a limiting criterion of 0.9Fy in the extreme tension reinforcement. Limiting steel stress to 0.9Fy is intended to ensure that there is elastic behavior and that cracks that develop during the passage of overweight vehicles will close once the vehicle is removed. It also ensures that there is reserve ductility in the member.

Steel structures shall satisfy the overload permanent deflection check under the SERVICE II load combination for design load and legal load ratings. Maximum steel stress is limited to 95% and 80% of the yield stress for composite and non-composite compact girders respectively (see MBE 6A.6.4.2.2). Service II checks for permit loads are recommended but optional. During an overweight permit review the actual truck weight is available, so a 1.0 live load factor is specified.

A tabulation of rating examples are included in Appendix A of the MBE.

3.15.3 Load Rating of New or Replacement Frames, Arches, Three Sided Structures and Culverts

The load rating analysis shall be performed by the designer in accordance with the Governing Specifications and the MBE using the live load models presented in this document.

If it is determined that the depth of fill is such that live load effects can be neglected then the structure would have an infinite safe load capacity for HL93, WV Legal Loads, and CRTS Trucks as long as the structure has residual capacity remaining after dead load effects have been considered.

A 3D Finite Element Analysis shall be performed for any structure that is constructed on a longitudinal slope to determine the out of plane load effects on the structure in the final condition.

Calculations shall be submitted to the Bridge Project Manager for approval prior to fabrication of any primary structural elements.

3.15.4 Load Rating of Gusset Plates

Load rating of gusset plates will be performed in accordance with *FHWA Gusset Guidance - Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges*, FHWA-IF-09-014, February 2009.

- When load rating gusset plates with unknown material properties, member strength should be obtained from the current version of the MBE.

- When checking the Limiting Slenderness Ratio (see FHWA Gusset Guidance 3.5) the unsupported edges of gusset plates should be evaluated in accordance based the following guidelines:

  Compression Edges $\frac{l}{t} \leq 1.648\sqrt{(\frac{E}{Fy})}$

  Tension Edges $\frac{l}{t} \leq 2.06\sqrt{(\frac{E}{Fy})}$

- All gusset plates rated using LFR will have the optional 0.9 reduction factor applied to the ratings as specified in the FHWA Gusset Guidance. This reduction factor is used to give the same reliability as the values obtained by LRFR ratings that uses the system factor to account for the non-redundant members.

3.15.5 Load Rating of Rehabilitated or Widened Structures

Load rating of structures using combination specifications within the superstructure (e.g. a superstructure designed by LRFD for the new widened superstructure elements and the original superstructure elements designed by Load Factor Design) shall not be permitted.

Load rating of structures partially reconstructed resulting in the use of combination specifications between substructure and superstructure elements (e.g. a reconstructed superstructure designed by LRFD supported by the original substructure designed by Allowable Stress Design, Load Factor Design, or unknown specifications) is permitted. The method of analysis for a reconstructed superstructure shall be Load and Resistance Factor Rating.

3.15.6 Conversion Factors for Refined Analysis

When structures are designed using refined analyses, conversion factors shall be developed. The refined analyses methods include line girder analyses based on refined live load distribution factors, grid analyses and finite element analyses. The conversion factors indicate the relationship of live load design moments and shears obtained from the refined analysis to the live load moments and shears obtained from a standard line girder analysis with a live load distribution factor of 1.0 for a single lane (a single lane equals two wheels). Do not use AASHTO distribution factors for the line girder analysis.

- The conversion factors for refined analyses shall be computed using the following equation:

$$CF = \frac{Moment\ (refined\ analysis)}{Moment\ (line\ girder\ analysis)}$$

- Use of conversion factors

Subsequent analyses of the structure may be completed using a standard line girder analysis with a live load distribution factor 1.0 for a single lane (a single lane equals two wheels). Do not use AASHTO distribution factors for the line girder analysis. For additional loadings, or re-evaluation of the design vehicle, the live load moments and shears obtained from the standard line girder analysis shall be multiplied by the conversion factors obtained from refined analysis at appropriate girder location under investigation. For example, for a presumed Girder 3 at mid-span of span 2, the equivalent refined moment can be calculated as follows:

Girder 3, Location: Span 2.5

CF = 1.026 (presumably listed in the table on the original plans)
$M_{(LG)}$ = 3175.8 K-FT (live load moment from line girder analysis)

$M_{(refined)}$ = 3175.8 K-FT (1.026)
= 3258.4 K-FT (equivalent refined live load moment)

3.15.7 Load Rating Plan Sheets

The required information for the plan sheet submittal is located in Section 4.4.1.18. Example plan sheets are also available for reference on the WVDOH website.

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APPENDIX A – MISCELLANEOUS PLAN NOTES

A.1 MANDATORY PLAN NOTES

A.1.1 Weathering (Unpainted) Steel Bridges

Note: All references in these notes are to the WVDOT, DOH Standard Specifications, Roads and Bridges, Adopted 2010 as amended by the Supplemental Specifications dated January 1, 2013, (or latest edition).

STRUCTURAL STEEL

All structural steel, except as noted, shall meet AASHTO M270 Grade 50W, except girder flanges, webs, and splice plates shall meet Grade 50W-T2.

High strength fasteners shall meet Section 709.24 and shall be black (uncoated) Type 3 (weathering steel). The high strength fasteners used in regions of the structure that require painting shall be Type 1 or 3 and shall be mechanical galvanized.

BLAST CLEANING AND PAINTING

Upon completion of all fabrication operations in the shop, and before shipment to the project site, all weathering steel bridge components shall be blast cleaned to a Near White surface condition according to SSPC-SP 10. Prior to the start of any blast cleaning, all oil, grease, cutting fluids, or other foreign matter shall be removed from the surfaces of the steel by solvent cleaning according to SSPC-SP 1.

The members or portions of members listed below shall be blast cleaned and shop painted according to Section 688 of the Standard Specifications, PAINTING STEEL STRUCTURES, using the Zinc Rich, Low VOC System, Section 711.22. Apply the full paint system in the fabrication shop, except faying surfaces of high strength bolted connections, which shall be shop painted with primer only. The color of the final top coat shall be 30045 according to Federal Standard 595 and the Gloss at angle of 60 degrees shall not exceed 25.

a) For integral and semi-integral abutment structures, paint the ends of the girders and all other structural components encased in the concrete abutment plus one additional foot in length.

b) Where expansion joints are specified, paint all steel components under the joint and in both directions from the centerline of the joint for a distance of 1.5 times the girder depth, or 10 feet, whichever is larger. Components specified to be hot-dip galvanized do not require painting.

Include cleaning and painting costs in Item 615001-*, Steel Superstructure.

IDENTIFICATION MARKING STEEL MEMBERS

All steel mill and fabricator identification markings for steel plates, shapes, or fabricated members shall be by metal tags, soapstone, or some other readily removable material; or, shall be marked in an area of the completed member which will be encased or covered with concrete. Marking methods and locations are subject to approval of the Engineer.

Do not use paint or wax-based crayons for marking.

HANDLING AND STORING STEEL MEMBERS

[This note has been added to the Standard Specifications.]

FINAL CLEANUP OF STRUCTURAL STEEL SURFACES

[This note has been added to the Standard Specifications.]

PROTECTION OF CONCRETE SUBSTRUCTURE

[This note has been added to the Standard Specifications.]

A.1.2 Deck Removal

DECK REMOVAL - GRINDING NOTE

After removal of the deck, the tension and stress reversal areas of the beam top flanges shall be inspected for the presence of unauthorized welds which may have been placed during the construction of the original deck, or during subsequent maintenance operations. Any such welds discovered shall be removed by thermal cutting the welds to within ¼ inch of the flange surface followed by grinding the remaining weld flush with the beam flange, or as may be otherwise directed by the Engineer. After grinding, the ground area of the beam flange shall be inspected by the contractor using magnetic particle (MT) testing to assure the absence of any cracks. Magnetic particle testing shall be performed in accordance with the currently adopted ANSI/AASHTO/AWS Bridge Welding Code D1.5 (BWC). Personnel performing the MT shall also be qualified in accordance with the BWC.

All grinding and MT shall be witnessed by individuals qualified as a Certified Welding Inspector (CWI) in accordance with the American Welding Society Standard for Qualification and Certification of Welding Inspectors QC-1. The Contractor shall notify the Engineer at least 48 hours prior to the start of any grinding or nondestructive testing. All work and costs associated with removal of the unauthorized welds, including MT and witnessing the work by the CWI, shall be paid to the contractor as Force Account Work in accordance with Section 109.4 of the Standard Specifications. Appropriate time extensions will be given due consideration by the Engineer.

A.1.3 Steel Stud Shear Connectors

<u>**STEEL STUD SHEAR CONNECTORS**</u>

[This note has been added to the Standard Specifications.]

A.2 TYPICAL PLAN NOTES

A.2.1 Elastomeric Bearing with Load Plate

[This note has been added to the Standard Specifications.]

A.2.2 Strip Seals

[This note has been added to the Standard Specifications.]

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A.2.3 Finger Joints

The fabrication and erection of the fingerplate shall be in accordance with the approved shop drawings and bridge deck grade and crown (profile). The openings shall be preset prior to shipment and assembled with temporary shipping angles. The fingerplate shall be installed under the supervision of the supplier.

The drainage trough shall not be spliced unless indicated on the approved shop drawings. When splices are indicated, the splices shall be shop vulcanized by the Manufacturer. Longitudinal splices are not permitted.

The Manufacturer shall be required to submit a detailed report substantiating the testing performed on its joint design and showing the corresponding fatigue resistance line generated from the actual fatigue testing data.

After the expansion joint is installed, it shall be tested for water tightness by flooding the expansion joint with water and inspecting from below.

A.2.4 Retaining Walls

[This note has been added to the Standard Specifications.]

A.2.5 Deck Slab Overhang Form

[This note has been added to the Standard Specifications.]

A.2.6 Erection Requirements

[This note has been added to the Standard Specifications.]

A.2.7 Lead Based Paint Coating

Project plans for repair, renovation, rehabilitation, replacement or demolition of existing highway bridges that contain lead based coatings shall contain a note as follows:

The Contractor's attention is directed to the fact that the existing structure contains lead based paint coatings.

A.2.8 Asbestos

[This note has been added to the Standard Specifications.]

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