Forest Service Handbook
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Forest Service Handbook 7709.56b – Transportation Structures Handbook
Chapter 70 - Road Bridge Design

Amendment: 7709.56b-2014-1

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Duration: This amendment is effective until superseded or removed.

Superseded Directive: 7709.56b,contents, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b, 0 Code Contents, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b, 0 Code, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b, 1 Contents, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b,1 Amendment, 7709.56b-94-1, July 27, 1994; 7709.56b, 2 Contents, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b,2, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b, 3 Contents, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b,3, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b, 4 Contents, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b,4, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b, 5 Contents, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b,5, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b, 6 Contents, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b,6, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b_7, Amendment 7709.56b-2005-1, August 26, 2005; 7709.56b_8, Amendment 7709.56b-2005-2, August 26, 2005; 7709.56b, 9 Contents, Amendment 7709.56b-94-1, July 27, 1994; 7709.56b,9, Amendment 7709.56b-94-1, July 27, 1994

Approved by: Gregory Smith, Acting Associate Deputy Chief, NFS

Date approved: November 18, 2014

Responsible Staff:

Explanation of changes: Following is an explanation of the changes throughout the directive by section.

7709.56b: The entire Handbook has been revised; refer to the digest for a summary of the revisions.

Zero Code: Makes minor technical and editorial changes, removes obsolete direction and terminology, and updates the coding system by changing from the one-digit to the two-digit coding system.

10: Recodes, reorganizes, and updates direction throughout the chapter. Makes minor technical and editorial changes, removes obsolete directions, and updates the coding system by changing from the one-digit to the two-digit coding system.

11: Recodes, reorganizes, and updates this section in its entirety. Replaces discussion of forest plans, ecosystem management, and least total cost method decisions with subsections on travel analysis and travel management decisions. Updates direction on road management to include direction on Trail Management Objectives and recodes the direction to section 11.3. Reduces scope of direction on alternatives to stay within limits of travel management decisions and the Road and Trail Management Objectives and recodes the direction to section 11.4. Recodes the remainder of the section to new section 11.5 entitled, "Project Development Process."

13: Sets forth new direction on inspection reports for existing structures and evaluation of load-carrying capacity of existing structures to listing of required design information.

20: Makes minor technical and editorial changes, removes obsolete direction, adds direction to meet Road and Trail Management Objectives, and updates the coding system by changing from the one-digit to the two-digit coding system throughout the chapter.

23: Adds direction to consider roadway widening needed to accommodate off-tracking of large trucks when curves are constructed close to bridges, to consider construction access to both sides of a stream, and to consider measures needed to maintain existing road traffic when replacing existing bridges.

30: Makes minor technical and editorial changes, removes obsolete direction, and updates the coding system by changing from the one-digit to the two-digit coding throughout the chapter.

34: Revises direction to conform to stream simulation requirements and to reference chapter 60.

35.4: Adds direction for identification of construction staging areas.

40: Makes minor technical and editorial changes and updates the coding system by changing from the one-digit to the two-digit coding throughout the chapter. Removes obsolete direction referencing economic analysis methods and flood insurance.

43.5: Updates direction to allow previously used materials only when they have been inspected, determined to be structurally adequate, economical and approved by the Regional Director of Engineering.

50: Changes chapter caption from "Hydrology" to "Hydrology and Geomorphology" and adds direction to require stream simulation and aquatic organism passage. Makes minor technical

and editorial changes and updates the coding system by changing from the one-digit to the two-digit coding system.

60: Changes chapter caption from “Hydraulics” to “Hydraulics and Watershed Protection” and adds direction to require stream simulation and aquatic organism passage. Makes minor technical and editorial changes and updates the coding system by changing from the one-digit to the two-digit coding system throughout the chapter. Removes obsolete direction.

70: Changes chapter caption from “Structural Design” to “Road Bridge Design” and updates the coding system by changing from the one-digit to the two-digit coding system throughout the chapter. Adds new direction and revises, reorganizes, and recodes direction throughout the entire chapter. Changes various section captions to be applicable for road bridge designs and sets forth new direction throughout the chapter. Removes obsolete direction.

80: Changes chapter caption from “Operations” to “Trail Bridge Design” and updates the coding system by changing from the one-digit to the two-digit coding system throughout the chapter. Sets forth direction for planning, design, and construction of trail bridges and other engineered trail structures.

90: Changes chapter caption from “Construction” to “Road Bridge Operation” and updates the coding system by changing from the one-digit to the two-digit coding system throughout the chapter. Revises, reorganizes, and recodes entire chapter. Major changes are: 1) removes the distinction and inspection requirements between bridges formerly known as NBIS and non-NBIS (National Bridge Inspection Standards), 2) removes all trail bridge references and guidance and 3) incorporates culvert guidance.

100: Establishes code, chapter “Trail Bridge Operation”, and sets forth direction for maintenance, inventorying, and operation of trail bridges and other engineered trail structures.

Table of Contents

70.6 - References

1. American Association of Highway and Transportation Officials (AASHTO). "Roadside Design Guide". Current Edition. The web address to order this publication is: https://bookstore.transportation.org/browse_bookstore.aspx.

2. AASHTO, AASHTO LRFD Bridge Design Specifications. Current Edition. The web address to order this publication is: https://bookstore.transportation.org/browse_bookstore.aspx.

3. AASHTO, Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400). Current Edition. The web address to order this publication is: https://bookstore.transportation.org/browse_bookstore.aspx.

4. AASHTO. A Policy on Geometric Design of Highways and Streets. Current Edition. The web address to order this publication is: https://bookstore.transportation.org/browse_bookstore.aspx.

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15. U.S. Department of Transportation, FHWA. Hydraulic Engineering Circular (HEC) 26, Culvert Design for Aquatic Organism Passage. The web address to order this publication is: http://www.fhwa.dot.gov/bridge/elibrary.htm.

16. U.S. Department of Agriculture, Forest Service (USDA-FS). Timber Bridges: Design, Construction, Inspection and Maintenance. EM-7100-8. August 1992. The web address to order this publication is: http://www.fpl.fs.fed.us/products/publications/.

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21. USDA-FS. "National Best Management Practices for Water Quality Management on National Forest Lands". Volume 1: National Core BMP Technical Guide. The web address to order this publication is: http://www.fs.fed.us/biology/resources/pubs/watershed/index.html.

71 - Design Standards for Roadway Bridges and Structures

Design bridges and other road structures requiring structural engineering in conformance with the provisions of AASHTO's LRFD Bridge Design Specifications, AASHTO's A Policy on

Geometric Design of Highways and Streets, and AASHTO's Guidelines for Geometric Design of Very Low-Volume Local Roads. These design specifications, policy, and guidelines, along with the references listed above, are the nationally accepted standards for road bridge design.

Any exceptions to AASHTO's design specifications and standards must be approved by the Regional Director of Engineering (FSM 7722.04c) and must be documented in the structural design calculations and maintained in the permanent bridge file. Design exceptions, use limitations, and special design requirements must be shown clearly on the project plans.

Prepare plans and construction specifications, including supplemental specifications, in conformance with the current edition of Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects.

71.1 - Standards for Design of Low-Volume, Low-Speed Road Bridges

Most National Forest System (NFS) road bridges carry low-volume, low-speed traffic. Most of AASHTO's design specifications and standards are written for higher-speed, higher-volume roads.

Geometric standards outlined in AASHTO's Guidelines for Geometric Design of Very Low-Volume Local Roads (sec. 70.6) should be used as the roadway standard for most NFS road bridges. Consider safety of the user when choosing design standards. Obtain approval of the Regional Engineer for and document any deviations from AASHTO's design specifications and standards, along with the rationale for the deviations, in the permanent bridge file (FSM 7722.1.7).

71.2 - Use of National and Regional Standard Designs and Plans for Road Bridges and Other Transportation Structures

As appropriate, use national and regional standard designs and plans for road bridges and other transportation structures. National standard designs and plans for road bridges and other transportation structures must be approved by the Washington Office, Director of Engineering. Regional standard designs and plans for road bridges and other transportation structures must be approved by the Regional Director of Engineering.
Establish Regional guidance regarding the use of standard designs and plans for road bridges and other transportation structures, including any delegation of design or approval authority. Where applicable, consider use of State standard designs and plans for road bridges and other transportation structures, and ensure that all required supplemental information is included in the construction contract plans or other documents.

72 - Design Requirements

72.1 - Bridge Widths

Use bridge widths that are consistent with applicable design criteria, elements, and standards.

1. Single-Lane Road Bridges. Use a 14-foot width as the minimum clear distance between traffic barriers for bridges, cattle guards, and other single-lane road structures. Use widths greater than 14 feet to accommodate curve widening, off-highway vehicles, and minor deviations (up to 2 feet) resulting from using standard modular structural units. Ensure that a single-lane bridge does not create the appearance of two lanes of traffic.

Structures on single-lane roads may have a minimum width of 12 feet if that width is adequate for the intended use and is not less than the width of the roadway approaching the bridge (FSH 7709.56, ch. 40, sec. 42.4, ex. 01).

2. Double-Lane Road Bridges. Use a 24-foot width as the minimum clear distance between traffic barriers for two-lane bridges, and in no case may the clear distance width be less than the approach roadway. Add curve-widening to both lanes on bridges and other roadway structures located along curves.

72.2 - Design Loads

The HL-93 loading identified in the AASHTO LRFD Bridge Design Specification is the minimum design live loading for NFS road bridges. The Regional Director of Engineering may authorize higher design loadings for bridges (FSM 7722.04b) in accordance with higher State design loadings or other special loading needs.

Use off-highway loadings for the design of structures when justified under FSM 7731.1.

Design for wind, seismic, and snow loads, and appropriate combinations, as specified in the AASHTO LRFD Bridge Design Specification (sec. 3.4.1-1).

72.3 - Road Bridge Traffic Barriers

Design and selection of road bridge traffic barrier systems should take into consideration the recommendations of AASHTO's Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT $\leq$ 400) and AASHTO's Roadside Design Guide. Use road bridge traffic barriers consistent with FSM 7721.1 and FSM 7722.12. Consider safety as the primary criterion for selection of road bridge traffic barriers. Document all decisions regarding road bridge traffic barriers in the permanent bridge file.

The primary purpose of road bridge traffic barriers is to contain and redirect vehicles using the road. All new traffic barrier systems should be crash tested (FSM 7720.5). Determinations of crashworthiness of road bridge traffic barriers must be made by a certified bridge design engineer.

Test Levels (TLs) have been established in AASHTO's Manual for Assessing Safety Hardware. The following standards govern application of TLs to NFS road bridges (see AASHTO's LRFD Bridge Design Specifications):

TL 1. Generally acceptable for work zones with low posted speeds and very low-volume, low-speed local streets. This TL applies to most NFS roads.

TL 2. Generally acceptable for work zones and most local and collector roads with favorable site conditions, as well as where very few heavy vehicles are expected and posted speeds are reduced.

TL 3. Generally acceptable for a wide range of high-speed arterial highways with very low mixture of heavy vehicles and with favorable site conditions.

TL 4. Generally acceptable for the majority of applications on high-speed highways, freeways, expressways, and interstate highways with a mixture of trucks and heavy vehicles.

* AASHTO's definition of low speed is less than 45 miles per hour.

Testing criteria for the chosen test level must correspond to vehicle weight and speeds and angles of impact shown below.

TL	TL Speed for Small Automobile With Crash Angle of 25°	TL Speed for Pickup Truck With Crash Angle of 25°	TL Speed for Single-Unit Van Truck With Crash Angle of 15°
TL 1	30	30	N/A
TL 2	45	45	N/A
TL 3	60	60	N/A
TL 4	60	60	55

A traffic barrier system must provide a smooth, continuous rail or curb on the traffic side. Posts should be installed on the reverse side of the rail. Structural continuity of rail components and anchoring at either end should be considered in the design.

Use a railing and deck connections that have been shown through crash testing to be satisfactory for the desired TL. Some modifications of the railing is allowable, provided it is crashworthy as modified. A crashworthy railing system may be used without further analysis or testing, provided that it does not have features that are absent from the tested configuration of the traffic barrier system that might detract from its performance. Determination of the crashworthiness of a railing must be made by a Bridge Design Engineer.

Provisions must be made to transfer loads from the traffic barrier to the deck. Traffic barrier loads are enumerated in Appendix A of AASHTO's LRFD Bridge Design Specifications. The bridge designer should select an appropriate TL based on the applicable maintenance level (ML) and design speed per FSM 7722.12. The following table displays the minimum requirements for road bridge traffic barriers systems on NFS roads and NFS lands.

ML	Minimum Required TL
MLs 1 & 2	TL 1
ML 3, Design Speed ≤ 30 miles per hour	TL 1
ML 3, Design Speed > 30 miles per hour	TL 2
MLs 4 and 5	TL 3

Once an appropriate TL has been determined, consider the following when identifying an appropriate traffic barrier:

1. Protecting the occupants of the vehicle in collisions with the barrier.

2. Protecting other vehicles and users near collisions.

3. Cost.

4. Appearance and ability to view scenery behind the barrier.

There are numerous crash-tested railing systems available. Generally, States have adopted specific crash-tested traffic barriers systems for TL 2 and higher.

Several curb only systems have successfully been crashed tested to TL 1. When curbs are used as a TL 1 traffic barrier, an approach guardrail is not required, provided properly located Type III object markers are installed at all four bridge corners. Type III object markers and other traffic delineators must be installed in compliance with the current edition of the MUTCD.

The minimum height for a TL 1 curb is 18 inches, measured from the deck running surface. Refer to AASHTO's LRFD Bridge Design Specifications for additional geometric requirements.

Delineation of a bridge, its traffic barrier, and approach guardrail is very important on narrow, low-speed roads. Consider object markers or traffic delineators whenever bridges are located on or near tight horizontal or vertical curves and at other critical locations.

72.4 - Approach Guardrail for Road Bridges

Include approach guardrail on all new road bridges with a TL 2 or TL 3 bridge traffic barrier. Design approach guardrail (transitions, length, and anchoring at either end) in conformance with the AASHTO's Roadside Design Guide. The approach guardrail must allow a gradual transition from the flexible approach railing to the more rigid bridge railing.

AASHTO's Roadside Design Guide defines and provides a formula for calculating minimum "length of need" of the approach guardrail length. The minimum "length of need" depends on

the variables that are defined and illustrated in chapter 5 of AASHTO's Roadside Design Guide. For very low-volume roads (ADT ≤ 400) with very low design speeds (< 30 miles per hour (mph)), the following values for these variables may be used:

1. Runout Length (Lr). Lr is the theoretical distance needed for a vehicle that has left the roadway to come to a stop. For a design speed of < 30 mph or less, the Lr may be taken as 130 feet.

2. Lateral Extent of Area of Concern (La). The La is the distance from the edge of the road to the far side of a fixed object that is a hazard or the outside edge of the clear zone. The hazard at a bridge is the end of the bridge railing. Where the bridge railing is aligned with the edge of the road, the La may be taken as 4 feet.

3. Tangent Length of Barrier Immediately Upstream of Area of Concern (L1). For low-volume and low-speed roads with flared approach railings, the L1 may be assumed to be 10 feet (approximately one-half the length of a typical transition section).

4. Flare Rate (FR). FR is the ratio of the length versus the lateral offset of the approach railing. For a design speed of 30 mph or less, the FR may be taken as 13:1.

Using the above values and a breakaway cable terminal (BCT) end treatment, the minimum length of approach guardrail for very low-volume, low-speed roads is 25 feet, with a lateral offset of 4 feet.

For design speeds greater than 30 mph, the minimum length of approach guardrail is 37 feet, 6 inches, with a lateral offset of 4 feet.

Other appropriate, approved, crash-tested approach guardrail systems are available. Contact the Regional Bridge Engineer to identify other systems meeting these criteria.

When using State or other Federal agency bridge railing plans, consider also using the associated approach guardrail plans.

72.5 - AASHTO Fatigue Design Stress

The average daily truck traffic on all but a very few NFS roads is very low; therefore, it is acceptable to allow exceptions to AASHTO fatigue design stress requirements in most NFS road bridge applications (FSM 7722.04b).

72.6 - Live Load Deflection

Deflection limits are left to the discretion of the road bridge designer in AASHTO's LRFD Bridge Design Specifications. User comfort is the primary determinant in setting deflection limits. Users are generally the driver and passengers in motor vehicles, although for bridges with sidewalks, pedestrian comfort also should be considered. At most sites, maximum deflection limits of L/400 are acceptable. In no case should design deflections be allowed to exceed L/240.

73 - Design Calculations and Plans

1. Complete structural and foundation design calculations and construction plans for each road bridge, culvert with a clear span greater than 20 feet, retaining wall higher than 6 feet, cattleguard, and other road structure requiring structural engineering under FSM 7722.1.

2. When road bridge and other transportation structure designs and plans are prepared by a Forest Service Engineer, ensure that they are reviewed by another Certified Bridge Design Engineer.

3. When road bridge and other transportation structure designs and plans are prepared by a Consulting Engineer, ensure that the designs and plans are reviewed by a Certified Bridge Design Engineer and bear the seal and signature of the responsible professional Engineer, registered in the State in which the bridge will be installed.

4. A Certified Bridge Design Engineer shall review all supplier or manufacturer product designs and plans in accordance with applicable Regional guidance and contract requirements (FSM 7722.1). Ensure that supplier or manufacturer product designs and plans bear the seal of the responsible professional Engineer registered in the State in which the bridge or products are manufactured.

5. Show foundation investigation, hydrological, and hydraulic data (FSH 7709.56b, chs. 30-60), design vehicles, and design loadings (for example, for snow and wind), as appropriate, on the plans. Show pile design bearing values, pile length or tip elevations, and bearing pressures on the plans.

6. Include as-built plans, design information, such as hydrology and hydraulics reports, geotechnical and foundation investigation reports, and preliminary design reports, as well as design calculations, for each road bridge in the permanent bridge file.

74 - Structure Life

When sizing the structure and selecting the type of material to be used for the structure, consider the following criteria:

1. Use long-term materials such as steel, concrete, aluminum, or appropriate preservative-treated wood. Do not use untreated log-stringer bridges as long-term permanent structures on National Forest System roads.

   a. Require air entrainment for concrete in Regions subject to freeze and thaw cycles.

   b. Galvanize, paint, or use weathering (corrosion-resistant) steel to reduce damage from oxidation.

   c. Use wood species that are either naturally resistant to deterioration (Refer to AASHTO M168) or treated using appropriate preservative treatments. Treat, clean,

and handle wood in conformance with the requirements of AWPA's Book of Standards and WWPI's Best Management Practices for the Use of Treated Wood in Aquatic and Other Sensitive Environments (sec. 70.6).

2. Design permanent structures to last at least 50 years. Design short-term structures for a lifespan appropriate for their intended use (sec. 43.3).

3. All structures should, at a minimum, be designed to withstand a 100-year flood with additional vertical clearance for the passage of woody debris and ice. The amount of additional vertical clearance should be based on Regional guidance and the requirements in FSH 7709.56b, chapter 50.

75 - Previously Used Materials

The use of previously used materials, particularly for structural elements, is discouraged in new bridges (sec. 43.5). The Regional Director of Engineering shall approve the use of any previously used materials.

Do not use railroad cars as road bridges on NFS roads.

76 - Culverts, Fords, and Low-Water Crossings

See FSH 7709.56b, chapter 60, for direction on the design of culverts, fords, and low-water crossings.

Culverts with a clear span greater than 20 feet must be designed by, or under the direct supervision, of a Certified Bridge Design Engineer or other Certified engineer approved by the Regional Director of Engineering (FSM 7722.04b and 7722.1, para. 1).

If no single culvert in a multiple-opening installation is greater than 20 feet, the Forest Engineer has design authority. For more detailed information on culverts, see the culvert matrix in FSH 7709.56, section 44.4.

77 - Channel Modifications

Design stream channels to simulate natural stream conditions (FSH 7709.56b, ch. 60). Balance the need for modifications against the potential damage to resource values, channel stability, and water quality.

78 - Temporary Road and Construction Bypass Bridges

Temporary road and construction bypass bridges intended for use by general forest visitor traffic or NFS administrative traffic must be designed by a Certified Bridge Design Engineer or a private professional engineer registered in the State in which the bridge is to be built, and reviewed by a Certified Bridge Design Engineer.

The following elements must be considered in each bridge design:

1. Loading (such as for the design vehicle, snow, and wind).

2. Bridge width.

3. Traffic barriers.

4. Length.

5. Substructure locations.

6. Freeboard.

7. Signing and traffic control devices.

8. Environmental controls or constraints.

79 - Privately Owned Road Bridges

Special-use authorizations for privately owned road bridges on NFS lands authorized by permit, term permit, lease or easement (special-use authorizations) should include clauses for design and construction requirements to adequately protect the public and National Forest System lands and resources. The design and construction requirements within FSM 7722 and the guidance in this section are recommended for all road bridges designed and installed on NFS roads or NFS lands, regardless of bridge ownership or road jurisdiction.

Permit holders are responsible for compliance with the requirements and engineering and construction costs of road bridges authorized by their permit.

The following technical advice is recommended for road bridges on roads authorized by a special use permit on NFS Lands.

79.1 - Design

Ensure that all bridge and approach roadway designs and calculations are:

1. Completed, signed, and sealed by a professional engineer registered in the State in which the bridge will be built.

2. Completed in accordance with the latest edition of AASHTO's LRFD Bridge Design Specifications. At a minimum, the bridge design must include appropriate approach roadways and site drainage, topographical site surveys, hydraulic and scour analysis, and geotechnical evaluation. Additional design criteria and guidance for bridge widths, approach roadways, and railing must be in accordance with AASHTO's Guidelines for Geometric Design of Very Low-Volume Local Roads.

3. Designed to accommodate a 100-year flood, with appropriate freeboard for debris, and to allow for passage of aquatic wildlife. At a minimum, abutments must be located outside the bankfull stream channel and installed so as to minimize resource damage.

4. Designed to provide drainage away from the bridge and stream, incorporate appropriate other drainage features, such as sediment traps and cross drains, and provide at least a 50-foot filtration or buffer from the stream channel for roadway drainage to reduce the flow of sediment into the stream.

5. Designed to include a traffic barrier and, if necessary, an approach guardrail system in compliance with FSM 7722.12 and FSH 7709.56b, sections 72.3 and 72.4. A Bridge Design Engineer shall evaluate which system to use in terms of public safety and consistency with AASHTO's Guidelines for Geometric Design of Very Low-Volume Local Roads.

6. Reviewed by the Forest Service Regional Bridge Engineer.

79.2 - Construction

Ensure that the registered professional Engineer who completed, signed, and sealed the design calculations, plans, and specifications establishes construction quality assurance measures, oversees these measures, and documents implementation of these measures. Upon completion of construction, ensure that the Engineer inspects the road bridge and certifies in writing that the structure was constructed in accordance with the approved plans and specifications. Ensure that the permit holder submits a copy of the inspection report and certification to the Forest Service.