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Sustainable Trail Bridge Design

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Cover photo—A field crew and trail maintenance equipment on a trail bridge.

Sustainable Trail Bridge Design

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National Technology and Development Program

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Contents

Executive Summary

The U.S. Department of Agriculture, Forest Service, is one of the most prominent Federal agencies when it comes to trail and trail bridge management. The Forest Service manages more than 158,000 miles of trails and more than 6,700 trail bridges. Designing trail bridges based on trail-specific Trail Management Objectives (TMOs) is essential for providing the desired trail experience, for ensuring user safety, and for maximizing bridge longevity. Managing a trail bridge for sustainability requires proper siting, good design details, routine inspections, and maintenance. Additionally, timely maintenance and repair are less costly than replacing bridges because of neglect or failure.

This report focuses on designing new, short, single-span, wooden trail bridges that the Forest Service classifies as minor and major trail bridges. This report also briefly addresses other bridge types and materials outside the minor and major trail bridge classifications. The Forest Service "Trail Bridge Catalog" website <http://www.fs.fed.us/eng/bridges/> provides further pictures and information on trail bridge types, decks, rail systems, materials, and abutments.

Introduction

The U.S. Department of Agriculture, Forest Service, manages about 6,700 trail bridges on National Forest System lands. The Forest Service is continually improving trail bridge design and construction techniques as new materials and new uses for existing materials become available. Bridges are an important feature of many trails, so it is essential to design them based on the desired trail experience (as indicated in the Trail Management Objectives [TMOs]) and for user safety and bridge longevity. Bridge design engineers must consider siting, design details and requirements, routine inspections, and maintenance when designing a structure for sustainability.

This report focuses on the design of new bridges that the Forest Service classifies as minor and major trail bridges (figure 1) (Forest Service Manual [FSM] 7737.05). These bridges are short, single-span trail bridges constructed of wood. National Environmental Policy Act (NEPA) requirements, landownership issues, and Federal and State permitting requirements are beyond the scope of this report.

Figure 1—A 15-foot span timber bridge classified as a minor trail bridge, which was constructed using Forest Service standard trail bridge plans.

This report is not intended as a comprehensive guide about trail bridge design, but should serve as a guide for basic knowledge about designing national forest single-span, wooden trail bridges. Having a background in construction and in-service inspection of trail bridges is valuable when designing trail bridges. An important aspect of effectively managing trail bridges is providing timely and quality trail bridge inspection and maintenance. It costs far less to maintain and repair a bridge than it does to replace a bridge that has failed because of neglect. Appendix A provides a copy of the "Trail Bridge Matrix," which the Forest Service uses for inspection requirements.

The Forest Service "Trail Bridge Catalog" website <http://www.fs.fed.us/eng/bridges/> provides further information and images of trail bridge types, decks, rail systems, materials, and abutments. This report also briefly touches on bridge types and materials that are outside the Forest Service definition for major and minor trail bridges.

Trail Management Objectives

One important criterion for designing trail bridges is meeting the TMOs for each trail. Trail bridge designs for National Forest System trails must reflect trail-specific TMOs (Forest Service Handbook [FSH] 7709.56b).

TMOs influence trail bridge design criteria by identifying the intended trail uses, trail experience, and accessibility requirements of each trail, the associated trail class and recreation opportunity spectrum, the trail width and other associated design parameters, and operation and maintenance requirements. Refer to FSM 2353 for further guidance on TMOs.

Siting

Site selection is critical in trail bridge design. Selecting a suitable site usually involves input from an interdisciplinary team (IDT) that typically consists of subject matter experts in engineering, trail management, hydrology, geoscience, and biology. It requires careful attention to hydrology, hydraulics, trail alignment, environmental, and geomorphic concerns. The IDT must address all of these concerns to ensure that the structure is appropriate for the site. The Forest Service National Technology and Development Program (NTDP) publication "Locating Your Trail Bridge for Longevity" <https://www.fs.fed.us/t-d/pubs/pdfpubs/pdf10232808/pdf10232808dpi300.pdf> (figure 2) covers siting in more detail.

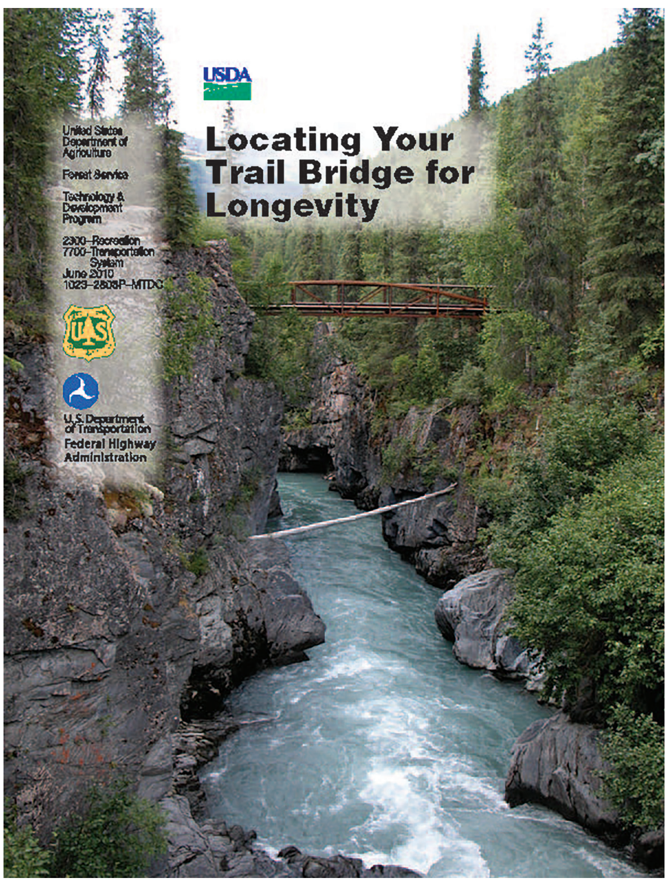

Figure 2—The Forest Service's "Locating Your Trail Bridge for Longevity" publication.

Additionally, FSH 7709.56b, Section 22, recommends that the IDT conduct site investigations at the most promising sites. The IDT must select an appropriate site where the trail and the trail bridge will achieve the TMOs. The IDT should also consider:

- Placing the crossing on a straight stretch of stream. However, in valleys where stream channels meander, the team should not rule out sharp bends as possible structure sites because these bends often indicate the presence of erosion-resistant material and a stable point in the stream reach.
- Avoiding crossing at a skew whenever possible.
- Avoiding curves and steep grades in trail alignment.
- Crossing at a narrow stream-channel section.
- Selecting sites with stable soils and slopes.
- Avoiding stream crossings where channels are subject to channel degradation, shifting, aggradations, or excessive scour. For example:
    - A poor site has easily erodible streambed and streambank material. Determining the depth of erodible material can help the team assess the site's suitability.
    - The stream reach at a good site location has been stable in both the horizontal and vertical direction in recent history.
    - Any upstream or downstream man-made structures might affect stream stability by changing waterflow patterns.
    - Crossings in alluvial fans may be unstable because streams through alluvial fans are subject to aggradation and sudden shifts in alignment. Preferably, cross near the apex or head of the fan.
- Using straight approaches to bridges of at least 50 to 100 feet in length if possible.
- Placing bridges on a slight grade where the trail geometry permits. A 2-percent grade works well for shedding water from a structure. Avoid bridge deck profile grades greater than 5 percent.

- Ensuring adequate clearance under a bridge to allow floodwaters, floating ice, or debris to pass during high runoff.
- Locating bridge substructures out of stream channels. Avoid constricting waterways with approach fills, abutments, or piers.
- When sizing a trail bridge and selecting the type of material to use, bridge design engineers should consult the trail-specific TMOs for guidance on the intended type of trail experience, the specific managed uses, and trail design parameters, including appropriate material types. Additionally, bridge design engineers should consider using long-term materials, such as steel, concrete, aluminum, or appropriate preservative-treated wood. Bridge design engineers may use untreated logs in some situations (e.g., for log foot bridges and trail bridges in designated wilderness areas) or for short-term uses, such as temporary bridges. However, treated wood or naturally decay-resistant wood will last significantly longer. Bridge design engineers should consider the following when selecting materials:
    - When practical, bridge design engineers should use wood species that are either naturally resistant to deterioration (refer to American Association of State Highway and Transportation Officials [AASHTO] M 168) or are treatable using appropriate pressure treatments. Treatment plants should treat, clean, and handle wood in conformance with the requirements of the American Wood Protection Association (AWPA) publication "AWPA Book of Standards" available at <http://awpa.com/standards> and the Western Wood Preservers Institute (WWPI) publication "Best management practices for the use of preserved wood in aquatic and sensitive environments" <http://preservedwood.org/portals/0/documents/BMP.pdf>.
    - Bridge design engineers should specify galvanized, painted, or weathering (corrosion-resistant) steel to reduce damage from oxidation on steel bridges.
    - Bridge design engineers should specify air-entrained concrete in regions subject to freeze and thaw cycles.
- Designing permanent bridges to last at least 50 years. Design short-term bridges for a lifespan appropriate to their intended use and in conformance with the TMOs for the trail.
- Designing all bridges to, at a minimum, withstand a 100-year flood. Provide for additional vertical clearance for the passage of woody debris and ice, as necessary. Refer to applicable regional guidance, channel configuration at the bridge site, and the requirements in FSH 7709.56b, Section 62.2, to determine the amount of additional vertical clearance.

Because a trail bridge is more susceptible to impact damage from debris, bridge design engineers should consider designing critical or high-value trail bridges with 1 foot more vertical clearance than the clearance required for a road bridge. Refer to the AASHTO publication "LRFD Guide Specifications for the Design of Pedestrian Bridges" for additional guidance on vertical clearances.

Bridge Types

There are six basic types of structures that bridge design engineers typically use for trail bridges:

- Deck girder and deck truss bridges
- Single-unit bridges
- Side girder and side truss (pony truss) bridges
- Arch bridges (deck or suspended)
- Cable bridges
- Covered bridges

The bridge design engineer should determine the appropriate bridge types and materials based on careful consideration of TMOs and site-specific factors, including crossing and span lengths. Different bridge types combined with various material types result in differing span capabilities and limitations. Not all bridge types and materials will work at all site locations. Longer crossings, in particular, may have a very limited selection of suitable bridge types and materials.

This guide focuses on the design of single-span, wooden deck girder and single-unit bridges included in the "USDA Forest Service Standard Trail Plans and Specifications" <https://www.fs.fed.us/managing-land/trails/trail-management-tools/trailplans>.

Bridge design engineers primarily use trail-specific TMOs to determine trail bridge type and material selection. The Forest Service "Trail Bridge Catalog" website <http://www.fs.fed.us/eng/bridges/index.htm> provides some general guidance on where different types of bridges will work and also has information about other types of structures. The website provides pictures, drawings, span guidelines, and comparisons.

Deck Girder and Deck Truss Bridges

Deck girder and deck truss bridges generally consist of two or more longitudinal stringers or trusses that support the top-mounted deck (figure 3). Deck girder and deck truss bridges span from 10 to 120 feet (table 1). Their decks are usually made of timber (log, sawn, or glued-laminated [glulam]), but may be fiber-reinforced polymer (FRP), concrete, or steel. Bridge design engineers recommend a minimum of three stringers or trusses for structural redundancy of the bridge.

Figure 3—A glued-laminated (glulam) deck girder trail bridge.

Table 1—Types of material and typical span lengths for deck girder and deck truss bridges

Bridge type	Material	Typical span length (feet)
Deck girder	Timber (log)	10 to 50
Deck girder	Timber (sawn)	10 to 30
Deck girder	Timber (glued-laminated)	20 to 100
Deck girder	Steel	30 to 120
Deck girder	Fiber-reinforced polymer	10 to 20
Deck truss	Timber	50 to 80
Deck truss	Steel	50 to 100
Deck truss	Fiber-reinforced polymer	20 to 80

Single-Unit Bridges

A single-unit bridge is a single, self-supporting unit that spans from 10 to 120 feet (table 2). People sometimes refer to timber-laminated and concrete bridges as "slab" bridges (figure 4).

Table 2—Types of material and typical span lengths for single-unit bridges

Material	Typical span length (feet)
Timber (log)	10 to 40
Timber (nailed or glued-laminated)	10 to 40
Prestressed concrete	30 to 120

Figure 4—A single-unit bridge with two timber slabs.

Side Girder and Side Truss Bridges

Side girder and side truss bridges generally consist of two longitudinal girders or trusses with floor beams or ledger beams attached to the inside of the main girders or trusses. Ledgers support transverse deck planks, and floor beams support longitudinal deck planks. On larger bridges, floor beams may support the stringers. The girders or trusses usually function as all, or part of, the handrail system (figure 5). Decks are usually timber (sawn plank or glulam), but may be concrete, steel, or FRP. Side girder and side truss bridges typically span from 40 to 240 feet (table 3).

Figure 5—A fiber-reinforced polymer bridge where the truss is also part of the handrail system.

Table 3—Types of material and typical span lengths for side girder and side truss bridges

Bridge type	Material	Typical span length (feet)
Side girder	Glued-laminated	60 to 120
Side girder	Steel	60 to 120
Side truss	Timber (log)	40 to 80
Side truss	Timber (sawn)	50 to 100
Side truss	Steel	50 to 240
Side truss	Fiber-reinforced polymer	20 to 100

Arch Bridges

Deck arch bridges generally consist of two arches below the bridge deck supporting longitudinal beams or walls, which in turn support the deck (figure 6). Suspended arch bridges consist of two arches, which extend above the bridge deck; longitudinal beams hung from the arches above with steel rods or cables support the deck. Decks can be timber (sawn plank or glulam), concrete, or steel. The longitudinal beams often function as tension members, holding the ends of the arch together. Often these arches are referred to as “tied arches.” Arch bridges span from 20 to 200 feet (table 4).

Figure 6—This masonry arch trail bridge was originally constructed for vehicle traffic.

Table 4—Types of material and typical span lengths for arch bridges

Component	Material	Typical span length (feet)
Deck arch	Timber	60 to 120
Deck arch	Masonry	20 to 60
Deck arch	Concrete (filled)	20 to 80
Deck arch	Concrete (open spandrel)	40 to 100
Suspended arch	Timber	60 to 120
Suspended arch	Steel	60 to 200

Cable Bridges

Two main steel cables support cable suspension bridges. The deck hangs from suspender cables or steel rods, which hang from the main cables. The main cables drape over towers at each end of the bridge. The embankment anchors the main cables, and the towers support them. Decks are usually sawn timber planks. Bridge design engineers usually design longer span cable suspension bridges with a stiffening truss under the deck.

Two main steel cables support simple suspension bridges (figure 7). The two main cables directly support the deck, so the deck follows an arc down and up from each abutment along the sag of the cables. The abutments anchor the cables, and intermediate towers may or may not support the cables. Decks are usually sawn timber planks. Two cables above the deck serve as handrails.

Figure 7—A deck cable bridge supported by two main cables on timber towers.

Multiple steel cables connected to the tops of one or more towers support cable-stayed bridges. Decks may be timber, concrete, or steel grid. The difference between suspension bridges and cable-stayed bridges is that the main support cables drape over the towers in suspension bridges; they connect directly to the towers in cable-stayed bridges. Cable bridges usually span from 40 to 400 feet (table 5).

Table 5—Types of material and typical span lengths for cable bridges

Type of cable bridge	Type of tower	Typical span length (feet)
Suspension	Timber	80 to 200
Suspension	Concrete and steel	80 to 400
Suspension	Tower without stiffening truss	80 to 120
Simple suspension	None	40 to 80
Simple suspension	Timber	40 to 120
Simple suspension	Concrete	80 to 300
Cable-stayed	Steel	100 to 400

Covered Bridges

Traditional covered bridges were essentially side truss bridges (figure 8). Most modern covered bridges use conventional side girders or deck girders. The covering is simply added to the top of the bridge to protect the structure from weather and deterioration. Covered bridges span from 10 to 300 feet (table 6).

Figure 8—Many old covered bridges are being converted into pedestrian bridges.

Table 6—Types of material and typical span lengths for covered bridges

Component	Typical span length (feet)
Timber side girder	50 to 80
Timber deck girder	40 to 80
Longitudinal glued-laminated deck	10 to 25
Traditional covered bridge	40 to 300

Materials

The Forest Service constructs most trail bridges using either timber or steel. However, in recent years the Forest Service has used aluminum, FRP, and concrete more often. Bridge design engineers should design and specify fabrication of bridges using materials that meet aesthetic, economic, and environmental constraints, while also taking into account installation and maintenance requirements.

Timber

Viable timber bridge designs use native logs, sawn timber, or glulam products and can use different types of surfacing (planed or rough-sawn) to alter the appearance of wood. Rough-sawn wood is not planed and is more appropriate for primitive locations or where bridges require antiskid characteristics. All wood products, including glulam, are available as rough-sawn. Rough-sawn glulam is generally referred to as “resawn” glulam.

Preservative treatments can significantly change the appearance, smell, and suitability of wood. A timber bridge design can specify preservative-treated wood, untreated wood, or a combination of both. For example, a design can specify untreated Alaska yellow cedar railing with treated glulam girders. The Forest Service follows requirements in the publication "AASHTO LRFD Bridge Design Specifications," which indicates that timber must be treated with a preservative (AASHTO M 133) unless it is considered high in heartwood decay resistance (AASHTO M 168) (table 7). Untreated wood that is not high in heartwood decay resistance typically has a design life of one-twentieth to one-fifth the life of treated wood and is usually an unacceptable alternative. Field crews can cut trees adjacent to the bridge site for native log stringers, handrails, and sills. These native logs are not required to be treated or high in decay resistance, although it is advantageous to locate trees such as those listed in table 7.

Table 7—Wood considered high in heartwood decay resistance, according to American Association of State Highway and Transportation Officials (AASHTO) M 168

Softwoods	Hardwoods
Bald cypress, old growth	Chestnut
Cedar	Black locust
Juniper	White oak
Redwood, old growth	Osage orange
Pacific yew	Black walnut

As mentioned in the "Siting" section of this guide, untreated, native log stringers may be appropriate for bridges in wilderness areas and other remote locations to meet visual requirements and in areas where transport by helicopters or mules is either too expensive or is not allowed. A bridge design engineer can evaluate trees near the bridge site for size and strength. The field crew can cut and move the suitable trees into place at the bridge site with cables, pulleys, and winches. Construction details that minimize water ponding on the bridge will maximize the life of the bridge.

The Forest Service typically uses Douglas fir or hem-fir on the west coast and southern pine on the east coast as preservative-treated timbers.

The AWPA introduced the Use Category System (UCS) in 1999 to provide a simple way to use the AWPA Standards (table 8).

The UCS assists the bridge design engineer with selecting and specifying the treatment for the end use of the product. The Forest Service uses the following treatments and UCS for their trail bridges:

- All treated stringers, decking, running planks, and handrails must be treated after fabrication in accordance with AWPA U1, UCS, using pentachlorophenol or copper naphthenate (CuN) in light oil, (type C solvent) for use category UC3B.
- All treated substructures (sills, backing planks, cribs, timber walls, etc.) shall be treated after fabrication in accordance with AWPA U1, UCS, using pentachlorophenol or CuN in heavy oil (type A solvent) for use category UC4B.

The Forest Service also requires that all treated timber members comply with the requirements of the current edition of WWPI's "Best management practices for the use of preserved wood in aquatic and sensitive environments" <https://preservedwood.org/portals/0/documents/BMP_Specifiers_Guide.pdf>.

If railing components are not treated or cut from naturally decay-resistant wood, the bridge design engineer should specify waterborne treatments or light solvent, oil-borne treatments for wood that trail users will frequently touch. Table 9 lists some of the most common preservative treatments and handling restrictions.

Table 8—A table summarizing the American Wood Protection Association use category designations

Use category	Service conditions	Use environment	Common agents of deterioration	Typical applications
UC1	Interior construction, aboveground, dry	Continuously protected from weather or other sources of moisture	Insects	Interior construction and furnishings
UC2	Interior construction, aboveground, damp	Protected from weather, but may be subject to sources of moisture	Decay fungi and insects	Interior construction
UC3A	Exterior construction, aboveground, coated, rapid water runoff	Exposed to all weather cycles, but not exposed to prolonged wetting	Decay fungi and insects	Coated millwork, siding, and trim
UC3B	Exterior construction, aboveground, uncoated, or poor water runoff	Exposed to all weather cycles, including prolonged wetting	Decay fungi and insects	Decking, deck joists, railings, fence pickets, and uncoated millwork
UC4A	Ground contact or freshwater, noncritical components	Exposed to all weather cycles, normal exposure	Decay fungi and insects	Fence, deck, and guardrail posts, crossties, and utility posts (low-decay areas)
UC4B	Ground contact or freshwater, components that are critical or difficult to replace	Exposed to all weather cycles, high decay potential, includes saltwater splash	Decay fungi and insects, increased potential for biodeterioration	Permanent wood foundations, building poles, horticultural posts, crossties, and utility poles (high-decay areas)
UC4C	Ground contact, freshwater, critical structural components	Exposed to all weather cycles, severe environments, extreme decay potential	Decay fungi and insects, extreme potential for biodeterioration	Land or freshwater pilings, foundation pilings, crossties, and utility poles (severe decay areas)
UC5A	Salt or brackish water and adjacent mud zone, northern waters	Continuous marine exposure (saltwater)	Saltwater organisms	Pilings, bulkheads, and bracing
UC5B	Salt or brackish water and adjacent mud zone, New Jersey to Georgia, and south of San Francisco	Continuous marine exposure (saltwater)	Saltwater organisms, including creosote-tolerant *Limnoria tripunctata*	Pilings, bulkheads, and bracing
UC5C	Salt or brackish water and adjacent mud zone, south of Georgia, Gulf Coast, Hawaii, and Puerto Rico	Continuous marine exposure (saltwater)	Saltwater organisms, including *Martesia* and *Sphaeroma*	Pilings, bulkheads, and bracing
UCFA	Fire protection as required by codes, aboveground, interior construction	Continuously protected from weather or other sources of moisture	Fire	Roof sheathing, roof trusses, studs, joists, and paneling
UCFB	Fire protection as required by codes, aboveground, exterior construction	Subject to wetting	Fire	Vertical exterior walls, in-roof surfaces, or other types of construction that allow water to drain quickly

Table 9—A table summarizing the properties of preservatives

Standardized use	Preservative	Solvent characteristics	Surface/ handling restrictions	Color	Odor	Fastener corrosion
All uses	Creosote	Oil-type	Oily, not for frequent human contact	Dark brown	Strong, lasting	No worse than untreated
	Ammoniacal copper zinc arsenate	Water	Dry, but contains arsenic	Brown, possible blue areas	Mild, short term	Worse than untreated wood
	Chromated copper arsenate	Water	Dry, but uses are restricted by the U.S. Environmental Protection Agency*	Greenish brown, weathers to grey	None	Similar to untreated wood
All uses (except in seawater)	Pentachlorophenol in heavy oil	No. 2 fuel oil	Oily, not for frequent human contact	Dark brown	Strong, lasting	No worse than untreated wood
	Copper naphthenate	No. 2 fuel oil	Oily, not for frequent human contact	Green, weathers to brownish gray	Strong, lasting	No worse than untreated wood
	Alkaline copper quat	Water	Dry, okay for human contact	Greenish brown, weathers to gray	Mild, short term	Worse than untreated wood
	Copper azole	Water	Dry, okay for human contact	Greenish brown, weathers to gray	Mild, short term	Worse than untreated wood
Aboveground, fully exposed	Pentachlor-ophenol in light oil	Mineral spirits	Dry, okay for human contact if coated	Light brown, weathers to gray	Mild, short term	No worse than untreated wood
	Oxine copper	Mineral spirits	Dry, okay for human contact	Greenish brown, weathers to gray	Mild, short term	No worse than untreated wood
Aboveground, partially protected (such as millwork)	Iodopropynyl butylcarbamate (IPBC) + permethrin	Mineral spirits	Dry, okay for human contact	Colorless	Mild, short term	No worse than untreated wood
Indoors (usually for insect protection)	Borates	Water	Dry, okay for human contact	Colorless, blue dye often added	None	No worse than untreated wood

* A few uses of chromated copper arsenate are still allowed for treatment of sawn products less than 5 inches thick (12.7 centimeters), such as dimension lumber. Pilings, poles, large timbers, and plywood are still allowed for highway construction.—Courtesy of USDA Forest Service, Forest Products Laboratory.

Steel

The bridge design engineer should specify steel that is painted or galvanized, unless it is a corrosion-resistant, weathering steel. Each of these types of steel treatments has its place in the field. The decision to paint a structure or use weathering steel depends on the local environmental conditions, the TMOs (including recreation opportunity spectrum classification), and consideration of the Forest Service "Built Environment Image Guide" <https://www.fs.fed.us/recreation/programs/beig/>. The Forest Service usually specifies using a Forest Service brown paint color for painted steel bridges.

Weathering steel is the steel of choice for most Forest Service steel bridges. However, bridge design engineers should consider important factors, such as environment and location, before selecting weathering steel for trail bridge construction. In general, bridge design engineers should not specify using uncoated, weathering steel in wet environments, including coastal areas or areas with high rainfall, high humidity, or persistent fog. Refer to the U.S. Department of Transportation, Federal Highway Administration, Bridges and Structures, Technical Advisory website <https://www.fhwa.dot.gov/bridge/t514022.cfm> for additional guidance on using weathering steel in specific locations.

Bridge design engineers and landscape architects generally do not prefer using galvanized steel for trail bridges on National Forest System trails; its bright, shiny, silvery color does not blend in well with the natural environment.

Concrete

Concrete is typically identified by its industrial grey appearance. The bridge design engineer can specify concrete to be texturized, colored, stained, or painted to better match aesthetic constraints. Texturizing tends to have long-lasting results and can be done with surface rollers, forms, form liners, sandblasting, or chemicals. Coloring can be done by adding coloring agents to the concrete or by staining and painting. Without periodic maintenance, concrete coloring tends to fade. The seal coat placed on colored and textured concrete may cause the surface to become slippery. One way to remediate this is to provide better surface traction by applying silica sand to the surface when the seal coat is tacky.

Concrete should have an air entrainment of 4 to 6 percent if it will experience exposure to freezing temperatures and should have a minimum design compressive strength of 3,000 pounds per square inch.

Fiber-Reinforced Polymer (FRP)

FRP, commonly referred to as fiberglass, is a composite material made of a polymer matrix reinforced with fibers. The fibers can be glass, carbon, aramid, or basalt. The polymer is usually an epoxy. FRP materials are lightweight and durable. Common shapes match those of the rolled-steel materials used for trail bridge components, such as tubes and channels. Fiberglass should have a waterproof, colored surface treatment (surface veil) to protect the fiberglass from ultraviolet radiation. Also, the structural components should be pultruded and not extruded. Fiberglass is available in a limited number of colors: green, brown, and gray. If applicable, the bridge design engineer can specify using higher cost components that manufacturers fabricate with a fire-retardant resin for bridge sites that are prone to fire damage.

Refer to the AASHTO publication "Guide Specifications for Design of FRP Pedestrian Bridges" and the NTDP publication "A Guide to Fiber-Reinforced Polymer Trail Bridges" (0623–2824P–MTDC) <https://www.fs.fed.us/t-d/php/library_card.php?p_num=0623%202824P> for further information about FRP trail bridges.

Plastic Wood

Plastic wood, or "wood-plastic composite" (WPC), is an alternative building material that manufacturers usually produce using recycled plastics and wood flour. WPC has a lower tensile strength and stiffness than wood and a much greater coefficient of thermal expansion than steel or wood, meaning that it expands and shrinks more. This contributes to significant long-term creep and deformations. For these reasons, when using plastic wood as decking and other nonstructural members, the bridge design engineer should develop special details to account for the creep and greater expansion.

Refer to the NTDP publication "Plastic Wood and Alternative Materials for Trail Structures" (1123–1804P–SDTDC) <https://www.fs.fed.us/t-d/php/library_card.php?p_num=1123%201804P> for further information about plastic wood.

Design

The Forest Service requires that all trail bridge design engineers follow "AASHTO LRFD Bridge Design Specifications" and AASHTO's "LRFD Guide Specifications for the Design of Pedestrian Bridges." These specifications, along with the additional references listed in FSH 7709.56b, Section 80.6, are the nationally accepted guidance for national forest trail bridge designs. In addition, trail bridge design engineers must follow AASHTO's "Guide Specifications for Design of FRP Pedestrian Bridges" when designing FRP bridges. Engineers must meet specific qualifications to design national forest trail bridges. A Forest Service employee can become a certified bridge design engineer by meeting education and experience requirements (FSM 7723.2). If a consulting engineer provides the design, a professional engineer must stamp the design (FSH 7709.56b, Chapter 80).

Bridge design engineers must design trail bridges to reflect the TMOs established for the trail. The TMOs indicate the appropriate trail fundamentals, recreational opportunity spectrum, and national quality standards for trails and applicable accessibility requirements. TMOs specify the trail class, intentionally managed uses, and trail-specific design parameters, including the trail width and other factors.

Bridge design engineers should design trail bridges for the maximum loading or load combinations, taking into account such factors as pedestrian live load, snow, wind, snow groomers, seismic events, and light vehicle loads. Design loads must reflect the trail fundamentals, including the design parameters that the TMOs identify for the trail (appendix B).

Bridge Widths, Grades, and Approaches

The required bridge width, bridge grade, approaches, and any accessibility requirements that the TMOs identify are important considerations that bridge design engineers must consider when designing a trail bridge.

Bridge Widths

The required trail bridge width depends on the intended uses of the trail as the TMOs specify, such as pedestrian, off-highway vehicles (OHVs), snow groomers, etc. Trail bridge widths can range from 18 inches wide (single-log foot bridge) to 14 feet wide or more (groomed, snowmobile trail bridge). A bridge design engineer who designs a bridge primarily for hiker and pedestrian use during the summer may also have to design the bridge to accommodate wider and heavier loads, such as trail maintenance equipment or emergency vehicles. Bridge design engineers should design trail bridges managed for both standard/terra trail uses during the summer and snow trail uses during the winter to accommodate the most demanding designed use that the TMOs identify.

Refer to the TMOs design parameters and "Forest Service Trails Accessibility Guidelines (FSTAG) Pocket Version" (1523–2812–MTDC) <https://www.fs.fed.us/t-d/php/library_card.php?p_num=1523%202812> for specific widths and other accessible trail requirements.

Grades and Accessibility

Grades for trail bridges should be consistent with the TMOs for the trail and should meet accessibility requirements, as applicable. Where trail geometry permits, bridge design engineers should place bridges on a slight grade (2 percent) to shed water. When grades exceed 4 percent, bridge design engineers should consider skid-resistant surfaces on high-use trail bridges or equestrian trail bridges. Bridge design engineers should avoid bridge deck grades of more than 5 percent on trails if they plan to meet accessibility requirements.

Approaches

Trail bridges should have straight approaches of 25 feet or more leading up to the bridge. Motorized trails should have straight approaches of at least 50 to 100 feet, if possible. Adequate line of sight is important for motorized trails; it enables users to see vehicles crossing the bridge or stopped on the bridge, allowing them time to stop. Another consideration for approaches is surface drainage and erosion control to keep water and debris from collecting on the bridge deck. The "Siting" section of this manual and the NTDP publication "Locating your Trail Bridge for Longevity" (1023–2808P–MTDC) <https://www.fs.fed.us/t-d/php/library_card.php?p_num=1023%202808P> provide further information about fitting a trail bridge to a site.

Users and Loads

The three major types of loads that bridge design engineers use in designing National Forest System bridges are dead loads, live loads, and snow loads. Other types of loads that bridge design engineers should consider are wind, seismic, and fatigue loads.

Bridge design engineers should design trail bridges for maximum loading or load combinations, taking into account such factors as pedestrian live load, snow, wind, snow groomers, seismic events, and light vehicle loads. Design loads must reflect the trail fundamentals, including the design parameters that the TMOs identify for the trail (appendix B). At a minimum, bridge design engineers must apply the provisions from AASHTO's "LRFD Guide Specifications for the Design of Pedestrian Bridges" covered in the following sections.

Dead Loads

Basic dead loads (stationary loads) consist of girders, stringers, beams, bracing, decking, and railing systems. Bridge design engineers may add additional dead loads, such as running planks, utility lines, a gravel surface, covers, etc.

Wearing surfaces (running planks), are a dead load and the Forest Service highly recommends applying them to protect the main decking for OHV, snowmobile, and equestrian trail bridges.

Live Loads

Live loads (moving loads) consist of pedestrians, bicycles, OHVs, equestrians, snowmobiles, and other temporary loads. The bridge design engineer should refer to the trail-specific TMOs to determine live loads to use in the design, taking into consideration all allowed uses, including managed, accepted, and administrative uses. The bridge design engineer should design trail bridges that are managed for both standard/terra trail uses during the summer and snow trail uses during the winter to accommodate the most demanding designed use that the TMOs identify. The bridge design engineer should also consider vehicle loads for emergency access and trail maintenance when determining live load requirements.

Per the AASHTO publication "LRFD Guide Specifications for the Design of Pedestrian Bridges" loads include pedestrian loading (people), vehicle loading (all-terrain vehicles [figure 9], motorcycles, bicycles, over-snow vehicles) and equestrian loading (packstock). The minimum pedestrian live load is 90 pounds per square foot (lb/ft²). AASHTO prepared the "LRFD Guide Specifications for Design of Pedestrian Bridges" for urban settings with large numbers of potential users. Many national forest trail bridge sites are remote and only small groups of hikers access them. When the TMOs indicate such limited use, the bridge design engineer can reduce the pedestrian load to 65 lb/ft². The bridge design engineer should document the justification for a reduced design live load and include it in the permanent bridge file.

Equestrian loads require bridge design engineers to design bridge decks for a patch load of 1,000 pounds over a square area measuring 4 inches on each side. Equestrian loads usually require thicker decking than pedestrian loads. Typical decking material for equestrian loads is 3 by 8 (or larger) planks. Bridge design engineers must design the entire trail bridge, including the deck, for the required uniform pedestrian or equestrian load in combination with other loads.

Figure 9—A single-unit timber bridge designed to accommodate all-terrain vehicles, bicycles, and hikers.

Bridge design engineers must design elevated viewing platforms for a minimum pedestrian live load of 100 lb/ft², according to Forest Service requirements (FSH 7709.56b, Chapter 80).

Snow Loads

Snow loads vary with geographic location and are often the heaviest load on national forest bridges, especially at high elevations and in northern latitudes (figure 10). Snow loads can vary from 0 lb/ft² in the South to 200 lb/ft² in the Northeast, and from 300 lb/ft² in California to more than 1,200 lb/ft² in the Cascade Range of Washington State. To determine snow loads, bridge design engineers should use the maximum ground snow load conditions, accumulation, and water content for the 50-year recurrence interval without reduction or use load values that local building or public road authorities have developed. Bridge design engineers should also consider snow loads as live loads and combine snow loads with other loads when applicable.

If designing for seismic events, a reasonable design methodology is to add 20 percent of the snow load to the dead load for determining total seismic weight.

The "Natural Resources Conservation Services Snow Telemetry (SNOWTEL) and Snow Course Data and Products" website <https://www.wcc.nrcs.usda.gov/snow> is one good resource for determining snow loads in the West. Site-specific snow load information is also available on the Applied Technology Council (ATC) website <https://hazards.atcouncil.org/>. The NTDP "National Snow Load Information" website <http://www.fs.fed.us/eng/snow_load/> provides further information about snow loads.

Figure 10—Trail bridges should be designed for snow loads.

Wind Loads

Wind loads for trail bridges are another live load. Bridge design engineers should use wind loads according to AASHTO's "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals;" AASHTO's "LRFD Guide Specifications for Design of Pedestrian Bridges;" or "AASHTO LRFD Bridge Design Specifications." A design using AASHTO's "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals" more accurately reflects the flexible nature of trail bridges, while a design using "AASHTO LRFD Bridge Design Specifications" is somewhat more conservative. Site specific wind load information is available on the Applied Technology Council (ATC) website <https://hazards.atcouncil.org/>.

Snow Groomer Loads

Snow groomer loads should reflect machinery currently in use or planned for use, as the TMOs or associated documents describe. Bridge design engineers should consider snow groomer loads as live loads and combine snow groomer loads with other loads. Grooming machines are very common on snowmobile trails in the Eastern United States. Older snow grooming machines weighed about 8,000 pounds, while newer snow grooming machines can weigh more than 20,000 pounds. Trail managers should be aware of the size of groomers that will be on the trail and how they compare to the size of the vehicle that trail bridge design engineers used for the bridge design.

Fatigue Load

Bridge design engineers only consider fatigue loads for steel members. Pedestrian loads on most national forest trail bridges do not significantly contribute to fatigue loading, so bridge design engineers do not normally consider them. When considering fatigue loads, bridge design engineers should refer to AASHTO's "LRFD Guide Specifications for the Design of Pedestrian Bridges."

Seismic Loads

The primary design consideration in seismic design is user safety. When designing for seismic loads, bridge design engineers should refer to "AASHTO LRFD Bridge Design Specifications." Site-specific seismic load information is available on the Applied Technology Council (ATC) website <https://hazards.atcouncil.org/>.

Maintenance Vehicles, Light Vehicles, and Emergency Vehicles

Bridge design engineers should consider vehicle loads for all trail bridges where artificial or natural physical barriers do not eliminate vehicle access. Bridge design engineers should also consider vehicle loads where field crews use motorized trail maintenance equipment (figure 11) to maintain trails. AASHTO requires engineers to design all trail bridges wider than 7 feet for light vehicle loads. Bridge design engineers should design trail bridges with deck widths (inside the railing systems) of 7 to 10 feet for a single H5 truck (10,000 pounds) and deck widths of more than 10 feet for a single H10 truck (20,000 pounds). The design should specify weight limit signs for bridges 7 feet and wider using R12-1 signs in conformance with the Federal Highway Administration "Manual for Uniform Traffic Control Devices" (MUTCD). The bridge design engineer can provide the appropriate weight limits for the signs.

Figure 11—Trail bridges should be designed to support applicable trail maintenance equipment.

For some trail and trail bridge locations, bridge design engineers should consider providing access for emergency vehicles, such as ambulances and firetrucks. The designer will need to design the trail bed and trail bridge to accommodate the heavier loads and vehicle widths.

Design Methodology and Load Combinations

Bridge design engineers should calculate trail bridge designs using load and resistance factor design (LRFD) and should consider all potential load combinations that may occur on a trail bridge. Bridge design engineers should design trail bridges using "Table 3.4.1-1—Load Combinations and Load Factors" from "AASHTO LRFD Bridge Design Specifications" and AASHTO's "LRFD Guide Specifications for the Design of Pedestrian Bridges." Additionally, the Forest Service includes five additional load cases for snow loads. AASHTO does not include any snow load combinations. Table 10 shows the basic load combinations the Forest Service uses.

Table 10—Load combinations and load factors the Forest Service uses to design trail bridge components

Description	Load combination and load factors*
Live loads	$1.25 \times D + 1.75 \times L$
Snow load only	$1.25 \times D + 1.75 \times S$
Snow trail users (case 1)	$1.25 \times D + 1.75 \times L + 0.50 \times S$
Snow trail users (case 2)	$1.25 \times D + 1.00 \times L + 1.75 \times S$
Snow groomer	$1.25 \times D + 1.75 \times L + 1.75 \times S$
Covered bridge (case 3)	$1.25 \times D + 1.75 \times L + 0.50 \times S$
Covered bridge (case 4)	$1.25 \times D + 1.00 \times L + 1.75 \times S$

* Abbreviations: *D* = Dead loads *L* = Live loads *S* = Snow loads

The AASHTO publication "LRFD Guide Specifications for the Design of Pedestrian Bridges" provides additional guidance on other load combinations.

In general, bridge design engineers should not combine maximum design snow loads with other live loads unless people use the trail bridge for winter activities. The procedure for determining loads for snow loads combined with other live loads is:

- Determine the appropriate design snow depth, the corresponding snow load, and live load for snow trail users (e.g., skier or over-snow vehicle), and analyze load combinations for snow trail users, cases 1 and 2. Use whichever snow and live load combination is most critical for snow trail users.
- Determine the appropriate design snow depth, the corresponding snow load, and the snow groomer load, and analyze the load combination for snow groomers.
- Determine the covered bridge roof snow loads and pedestrian live loads for the underlying deck, and analyze load combinations for covered bridge, cases 3 and 4. Use whichever snow and live load combination is most critical for covered bridge.

In general, wind loads are not critical for most trail bridges. However, for longer trail bridges with high exposure that are subject to high winds, the designer should use the following conditions when analyzing the bridge:

- Do not consider wind on live loads.
- Do consider wind pressures on vertical snow-loaded areas.
- Check the bridge for overturning and sliding.

Forest Service Standard Trail Bridge Plans and Specifications

The Washington Office, Director of Engineering and Director of Recreation, approved the “Forest Service Standard Trail Bridge Plans and Specifications” for superstructure standard plans, substructure design aids, standard construction specifications, and pay items (figure 12). The plans and specifications are available at the “USDA Forest Service Standard Trail Plans and Specifications” website <https://www.fs.fed.us/managing-land/trails/trail-management-tools/trailplans>. Excerpts from the aforementioned specifications that relate to steel and timber trail bridges are provided in appendix D.

Forest Service personnel should use these standard plans and specifications for trail bridges. The regional director of engineering must authorize and approve any regional changes or new standard plans. Each region may establish regional guidance regarding the use of standard designs and plans, including any delegation of design or approval authority.

Bridge design engineers must still use preliminary engineering analysis and site-specific engineering design when they use standard plans and specifications. A certified bridge design engineer should

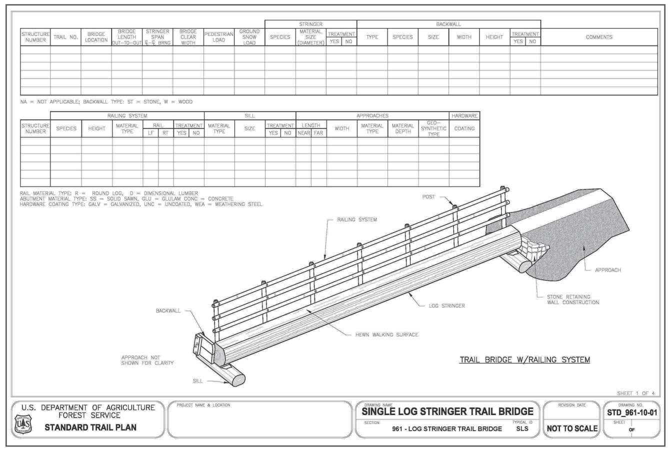

Figure 12—An example of a standard trail bridge drawing from the Forest Service "Standard Trail Bridge Plans" publication.

prepare or directly supervise the preparation of site-specific engineering designs. FSM 7723.04 provides direction about who has the authority to review, approve, and sign site-specific engineering designs. FSH 7709.56b, Section 10 and Section 60, and the NTDP publication “Locating Your Trail Bridge for Longevity” provide information about bridge siting.

When a trail manager proposes a bridge design that is not included in these standard plans and specifications, the regional director of engineering or an engineer of record (outside the Forest Service) must approve the plans and specifications being used. A professional engineer or Forest Service-certified bridge design engineer must design any modifications to a bridge, document and cite the modifications in the structural design calculations, and maintain documentation in the permanent bridge file. The bridge file should include all the items listed in appendix C. The project plans must clearly show any design exceptions, use limitations, or special requirements (FSH 7709.56b, Chapter 80).

Timber Bridges

The Forest Service has approved six different types of timber trail bridge plans and specifications as standards:

- “Single Log Stringer” (STD-961-10)
- “Multiple Log Stringer” (STD-961-20)
- “Sawn Timber Stringer” (STD-962-10)
- “Longitudinal Nail-Laminated” (STD-962-20)
- “2- and 3-Beam Glulam Stringer” (STD-963-10)
- “Longitudinal Glulam Deck Panel” (STD-963-20)

The “Standard Specifications for Construction of Trails and Trail Bridges on Forest Service Projects” provides the pertinent specifications in sections 961, 962, 963, and 995 (“Material for Timber Structures” in appendix D).

Prefabricated Steel Bridges

The Forest Service has also approved the use of Prefabricated Steel Trail Bridges (STD-964-10) (figure 13). The “Standard Specifications for Construction of Trails and Trail Bridges on Forest Service Projects,” section 964 (in appendix D), provides the standard for prefabricated steel trail bridges. A licensed, professional engineer must perform or directly supervise the structural design of prefabricated steel bridges. The bridge design engineer must also have a license in the State where the bridge fabricator is located. As with timber bridges, a bridge design engineer must design prefabricated steel bridges in accordance with “AASHTO LRFD Bridge Design Specifications” and as recommended in AASHTO’s “LRFD Guide Specifications for Design of Pedestrian Bridges.”

The bridge design engineer must design prefabricated steel bridges for (at a minimum):

- A pedestrian load of 90 lbs/ft^2 with live load deflection not to exceed L/360.
- An occasional single maintenance vehicle with no impact factor required.

Figure 13—Prefabricated steel bridges are included in the standard trail bridge plans and specifications.

- A vehicle load of 10,000 pounds (H5 design vehicle) for a clear deck width (between railings) more than 7 feet and less than 10 feet and a vehicle load of 20,000 pounds (H10 design vehicle) when the clear deck width is more than 10 feet.
- Load combinations of snow, equestrian, wind, and fatigue loads, as specified in the “AASHTO LRFD Bridge Design Specifications.” When the snow load is more than the 90 lbs/ft^2 pedestrian load, analyze and design for the controlling load. For a snow load, controlled design deflection may not exceed L/240.
- The vibration “fundamental frequency” of the pedestrian bridge without live load should be more than 3.0 hertz in the vertical direction and 1.3 hertz in the lateral direction. The bridge design engineer should determine the minimum fundamental frequency for loads other than pedestrian loads, such as equestrian and mule trains.
- The bridge should have a vertical camber dimension at midspan equal to 100 percent of the full dead-load deflection plus 1 percent of the full length of the bridge.

Trail Bridge Structure

The Forest Service definition of a bridge is "a structure, including supports, erected over a depression or an obstruction, such as water, along a road, a trail, or a railway and having a deck for carrying traffic or other loads."

The substructures, superstructure, decking, user barriers, and approaches are typical components of a bridge. The "Design" section of this guide provides information about approach design.

Substructures

Trail bridge substructures, which consist of two or more abutments, are the supports that carry the load to the ground. Substructures are typically site-specific. The bridge design engineer will consider the bridge opening requirements, ground cross section, foundation material, and bridge span and loadings to determine the type, shape, height, and material for the substructure abutments. The bridge design engineers must take into consideration the stream's floodflows when crossing a body of water and the effects of stream scour when they select the abutment type and design. Intermediate bridge supports (piers) are particularly susceptible to scour, damage from streamflow, and debris loading. The bridge design engineer should design all bridge abutment and pier footings at, or below, the anticipated scour elevation.

Bridge substructure design generally requires input from an interdisciplinary team that includes a forest engineer, a soil scientist, a hydrologist, a geotechnical engineer, and a structural engineer. The team determines the allowable soil pressures and scour potential and discusses the appropriate foundation types that fit the site. A stable foundation is very important for the structure and keeps the foundation from settling or giving way. Taking the time to conduct an adequate soil investigation and calculate scour is invaluable.

The bridge design engineer should locate and design substructures for short-span bridges outside of the stream channel. This reduces the chance of constricting waterways with approach fills or abutments. An experienced bridge design engineer must design abutments and piers for longer span bridges. Abutment types may vary from one side of a stream to the other, depending on the cross section of the stream channel.

Abutments

A sill abutment is a single-element foundation placed on compacted gravel fill that supports the bridge superstructure. Sills can be made from logs, sawn timber, glulam, plastic wood, concrete, or gabion baskets. Gabion or concrete abutments often have a timber cap to facilitate connecting a steel or timber bridge to the abutment.

Retaining wall abutments are earth-retaining structures that also support the trail bridge superstructure. These abutments may consist of log, sawn timber, timber tiebacks, steel tiebacks, pilings, gabion baskets, concrete, or masonry.

The "USDA Forest Service Standard Trail Plans and Specifications" website <https://www.fs.fed.us/managing-land/trails/trail-management-tools/trail-plans> provides substructure design aids for simple abutments to assist with the design of short-span bridges.

Piers

Piers are intermediate bridge supports for multi-span continuous stringer or multiple, simple-span bridges. Typical bents or piers are made from timber piling, timber frame, or cribs. Bents are normally constructed from driven piling and have a timber or concrete cap. Cribs are grillages forming one or more gravel- or rock-filled compartments.

Superstructures

Trail bridge superstructures carry the loads from the deck to the substructure. Bridge design engineers design superstructures for two limit states or conditions: strength and serviceability.

Bending and shearing are the two potential ways a bridge can fail using strength criteria. When a simple-span stringer is loaded, it bends and causes the top of the stringer to compress and the bottom of the stringer to go into tension. The stringer fails when the extreme fibers fail by either crushing in compression or pulling apart in tension, which usually occurs at the mid-span of the bridge. Shear can be either vertical or horizontal and normally occurs above the support at the abutment. For wood members, horizontal shear occurs when the beam separates along the neutral axis, and vertical shear occurs when the member shears at the end of the stringer.

Deflection is a serviceability limit state and is sometimes referred to as a personal comfort factor. Many people are uncomfortable when a bridge bounces or sags; they feel that the bridge is going to fail. A bridge with too much deflection may bounce excessively and knock people off the bridge as they walk across it.

"AASHTO LRFD Bridge Design Specifications" specify the nominal resistance values for bending and shear and provide guidance on the allowable deflection limit as a ratio of span length divided by a value that depends on the stringer material type. A basic rule of thumb is that bending controls stringers shorter than 28 feet and deflection controls stringers longer than 28 feet.

Decking

Decking supports live loads and transfers the weight to the superstructure. The bridge design engineer often designs trail bridge decks with the same, or similar, material as the rest of the bridge. Wood is the most common trail bridge deck material. Preservative-treated or decay-resistant wood extends the life of the deck.

The Forest Service recommends using waterborne preservative or oilborne preservative in light solvent for areas of frequent human contact. The bridge design engineer should not suggest use of oilborne preservative in heavy oil for pedestrian bridge decks and rails because the treatment chemicals and the oil solvent will get on skin and clothing. Table 9 lists the surface and handling restrictions and indicates which treatments are acceptable for human contact. For further information about preservative treatments, refer to the NTDP publication "Preservative-Treated Wood and Alternative Products in the Forest Service" (0677–2809P–MTDC) available at <http://www.fs.fed.us/eng/php/library_card.php?p_num=0677%20 2809P>.

The bridge design engineer and the maintenance crew should take care to provide a deck surface that does not become slick from use, particularly if the bridge has equestrian, bike, or motorcycle traffic or is on a grade. The bridge design engineer can specify use of timber cleats, rubber matting, or other wearing surfaces to increase traction.

Decking Types

Field crews can cut logs for decking from small-diameter trees onsite and can install the logs without preservative treatment. The resulting surface is rough and has an expected life of just 2 to 12 years.

Sawn timber plank decking can be transverse (perpendicular to the load-carrying members) or longitudinal (parallel to the load-carrying members). The bridge design engineer should specify pressure-treated planks. Untreated planks have an expected life of only 2 to 10 years, whereas treated planks have an expected life of 25 years or more. The bridge design engineer should specify a waterborne preservative if skin contact might occur.

Bridge design engineers typically specify glulam timber decking for heavily loaded bridges in rural and urban areas. Bridge design engineers usually design glulam decking to be perpendicular to the direction of travel. Glulam decking has an expected life of 25 years or more.

Concrete decks are usually only feasible for bridges with road access because concrete is difficult to mix and transport.

For steel grid decks, bridge design engineers specify premanufactured grating supplied by a number of companies.

Fiberglass decks are usually flat fiberglass sheets bonded to shallow fiberglass structural shapes. Manufacturers embed coarse sand into the gel top coating of the flat sheets to increase roughness.

User Barriers

Trail bridge user barrier design (curbs and railings) should be site-specific. The bridge design engineer and landscape architect collaborate to design user barriers for trail bridges. Short-span bridges with a single log and minor trail bridges close to the ground do not need user barriers because they would be impractical for field crews to install or the TMOs do not require them. The bridge design engineer and local recreation staff should evaluate the physical characteristics and user-safety needs at each site using the applicable TMOs as a guide. Trail bridge user barriers can be curbs, railing systems, or a combination of the two.

User Barrier Types

If the TMOs for a trail bridge on a trail intended only for nonmotorized use indicate the need for a user barrier, consider the following in the design with appropriate AASHTO and accessibility codes:

- Heavily used trails, particularly near urban areas, may require a building code-based rail system that meets the following geometric provisions:
    - The top rail must be at least 42 inches high, measured from the deck surface.
    - A 4-inch-diameter sphere must not pass through the bottom 36 inches of the rail. A 4$^{3}/_{8}$-inch-diameter sphere must not pass through the rail above 36 inches (International Building Code [2015], 1015.3 and 1015.4).

Although not a building code requirement, the rails should be vertical so that children cannot climb them and a person in a wheelchair can look through them with no visual impairment.

The building code-based rail system is appropriate for urban areas and adjacent recreation areas where visitors are more likely to be inexperienced hikers and groups with small children. Scenic views like waterfalls and other areas that receive a lot of visitors and children should also have this type of railing system.

- Moderately used trails, typically in rural areas, may require an AASHTO-based railing system that meets the following geometric provisions:
    - The top rail must be at least 42 inches high, measured from the deck surface.
    - A 6-inch-diameter sphere must not pass through the bottom 27 inches of the rail. An 8-inch-diameter sphere must not pass through the rail above 27 inches.
- Low-use trails may require an OSHA-based railing system that meets the following geometric provisions:
    - The top rail must be at least 42 inches high, measured from the deck surface.
    - The railing system must include a top rail and an intermediate rail. The space between horizontal rails must not exceed 19 inches. When the engineers design this type of railing system on equestrian trails, they should also include a curb or kick rail.

When the TMOs indicate that a curb will be adequate, the curb should consist of a top longitudinal rail blocked up off the deck surface (scupper blocks) to allow drainage. The curbs and blocks may vary in height and size, depending on the managed use of the trail. As a general rule of thumb, a trail bridge with a drop of 4 feet or greater should have a rail system. In general, if the trail bridge is in a remote location, a drop of 8 feet or greater requires a rail system.

User barriers for bicycle trail bridges should be a minimum of 42 inches high, but 54 inches is recommended. Pedestrian and bicycle railing systems are usually adequate for other trail users, such as equestrians, motorcyclists, over-snow vehicle users, all-terrain vehicle users, snowshoers, and cross-country skiers.

User Barrier Design Loads

The bridge design engineer should design all trail bridge user barriers for the design loads in “AASHTO LRFD Bridge Design Specifications” and should consider the following:

- Design each rail, including curbs, for a uniform load of 50 pounds per linear foot simultaneously applied horizontally and vertically, and a 200-pound load simultaneously applied at the most critical location and most critical direction.
- Design each post and curb connection for the uniform horizontal load acting on the top rail with a 200-pound horizontal load simultaneously applied at the top rail.

All trails intended for motorized use may require road bridge traffic barriers. All rails and curbs must meet the static strength requirements for the intended user in “AASHTO LRFD Bridge Design Specifications.”

Signage

Bridge design engineers may specify marking bridge railing end posts on trails managed for motorized or bicycle use with Type 3 object markers (per the FHWA publication “Manual of Traffic Uniform Control Devices” and the Forest Service publication, EM 7100-15, "Sign and Poster Guidelines for the Forest Service") to delineate the bridge ends that intrude on the trail.

Construction Details and Constructability

Good design and construction details, such as materials appropriate for the environment, connection design, and construction details that prevent ponding water, are important for the longevity of a trail bridge.Two helpful articles on increasing the life of a bridge are “Durability and detail design—the result of 15 years of systematic improvements” by Kropf (1996) <https://www.fs.fed.us/eng/bridges/documents/desinpln/Durability_And_Detail_Design.pdf> and “Controlling Decay in Waterfront Structures” by Highley and Scheffer (1989) <http://www.fs.fed.us/eng/bridges/documents/tdbp/contdeca.pdf>. Kropf (1996) describes designs used in Europe, where the use of treated timber is not as common as in the United States, and provides details about shedding water from the structure to prevent decay. Highley and Scheffer (1989) provide information about controlling decay in waterfront structures.

The Forest Service “Forest Products Laboratory” website <http://www.fpl.fs.fed.us/products/publications/> and the “National Center for Wood Transportation Structures” website <http://woodcenter.org/> provide additional articles about construction details.

Information in the following sections, with appropriate application, should increase bridge longevity. Refer to the NTDP publication “Innovative Design for Short-Span Timber All-Terrain Vehicle Trail Bridges” (1223–2316P–MTDC) available at <http://fsweb.mtdc.wo.fs.fed.us/php/library_card.php?p_num=1223%202316P> for additional information and details about improving bridge longevity.

Shedding Water and Debris

Shedding water from a bridge helps reduce decay of the bridge and its components (figure 14). A few useful details that can help with shedding water are:

- Bevel the tops of rail posts at a 30-degree angle to shed snow and water. Water and snow will collect on the top of a flat post and the end grain will wick the water in. This is a prime location for decay to begin.
- Raise the lower rail an inch or more off the deck or install scupper blocks under the curbs to allow water and debris to run off. Trapped debris will also trap moisture and promote decay.

- Construct the bridge with a minor slope of 2 percent to shed water and debris from the bridge.
- Avoid locating a bridge at the low point of a sag curve where it can collect water and debris.
- Prevent approaches from channeling water onto the bridge by:
    - Constructing drain dips to drain water off the trail before it reaches the bridge.
    - Constructing flare ditches to funnel water away from the bridge.
- Clear trees and brush from around the bridge to allow air to flow around the bridge and to enable the bridge to dry out.
- Install metal flashing on top of timber piling before installing stringers and on top of wood stringers before installing decking to help keep the wood dry.

Figure 14—Low-use trail railing system with beveled posts to shed water.

Earth and Wood Contact

The earth-wood interface is another area where decay commonly occurs. Any location where dirt contacts the wood may accumulate water and begin the wood-decay process. Sills and backwalls are the main bridge components located at these areas. Treated or decay-resistant wood are the best options for these components.

Installing backwalls at the ends of the bridge stringers provides another practical design detail to help keep the stringers and sills clean and free of dirt (figure 15). The backwall planks should extend beyond the sides of the bridge to help keep dirt from wrapping around the backwall and accumulating on the sills next to the stringers. Backwalls help to prevent the approach fill adjacent to the bridge from eroding. Backwalls also help to reduce moisture from wicking into the end grain of the stringers. Constructing a small air gap using ½-inch-thick by 2-inch-wide boards between the ends of the stringers and backwall will allow air to flow around the ends of the stringers and will reduce moisture from being trapped.

Figure 15—Backwalls should be extended to prevent the soil from contacting the beams.

Screws Versus Nails

Screwing decking down instead of nailing it in place is another good construction and maintenance detail. Nails can loosen over time, while screws are more stable and can be retightened. Decking that is screwed down is easier to replace by simply unscrewing the deck screws and replacing the decking. Decks that are nailed down are harder to replace, especially when ring shank nails are used. Pulling these nails, with their ridges and grooves, out of a timber plank may cause damage to the wood fibers.

Through Bolts Versus Lag Screws

Using through bolts instead of lag screws is a good detail for fastening wood members together. Lag screws work well until the wood strips out or decays around the screw. Through bolts can be tightened, even if decay is present around the bolt. Using carriage bolts to attach railings to posts instead of using lag screws increases the life of the connection. Another construction detail that works well is using all-thread rods to attach railing system posts to log foot bridges.

Weathering Steel Corrosion Problems

Using weathering steel in certain locations has resulted in corrosion issues. The bridge design engineer should evaluate the weathering steel before field crews use it. It is possible under humid conditions that a protective patina may not develop and the weathering steel may instead continue to rust (figure 16). The following environmental conditions and locations should be avoided when considering weathering steel:

- Marine coastal areas
- Areas with frequent rainfall, high humidity, or persistent fog
- Areas with tunnel-like conditions or little exposure to sunshine
    - Low bridge height over water
        - 10 feet over stagnant water
        - 8 feet over moving water
- Areas with dense surrounding vegetation
- Areas close to rock cliffs or in deep canyons

Refer to the U.S. Department of Transportation, Federal Highway Administration, "Technical Advisory T5140.22—Uncoated Weathering Steel in Structures" website <http://www.fhwa.dot.gov/bridge/t514022.cfm> for further information.

Figure 16—A weathering steel floor beam with corrosion issues in a humid climate.

Corrosiveness of Wood Treatments

The U.S. Environmental Protection Agency (EPA) worked with pesticide manufacturers to voluntarily phase out chromated copper arsenate (CCA) use for wood products. Effective as of December 31, 2003, the EPA no longer allows CCA for residential uses. See table 9 for a list of how different preservative treatments compare with untreated wood.

New preservative treatments on the market that have replaced CCA are more corrosive to metals. The treated-wood industry recommends use of stainless steel or hot-dip galvanized fasteners and connectors. Check with the product manufacturers to ensure that fasteners, connectors, and the type of wood treatment used are compatible.

One fastener manufacturer—Simpson Strong-Tie—conducted its own tests. Simpson Strong-Tie found that some of the alternative treatments were slightly more corrosive than CCA. They offer a ZMAX coating that protects their fasteners from corrosion caused by new wood preservative treatments. The "Simpson Strong-Tie" website <http://www.strongtie.com/productuse/corrosion.html> provides general information about corrosion and about preservative-treated wood.

Decking

Extending decking over the top of the backwall planks helps prevent water from running down between the backwall and bridge stringers. This reduces the chance that the end grain of the stringers will absorb moisture and create an environment that promotes decay. Hanging the decking over the sides of the stringers by 6 inches makes installing the curb easier. It also allows water to run off the end of the decking and prevents it from running down the sides of the stringers.

Approaches

Where appropriate per TMO specifications, installing paving blocks at the bridge approaches can help prevent potholes and settling in the approach trail embankment. Paving blocks can also prevent surface erosion caused by ATVs, bicycles, and horses. The design should specify the last courses of the blocks on a 5-percent downslope into the adjoining trail tread and backfill with suitable tread material to meet the trail grade. The blocks are laid against the end of the bridge deck to help drain water away and stabilize the trail transition material. Another viable approach foundation design is geocell that helps stabilize approaches and contain approach fill. A minimum fill of 4 inches should cover the tops of geocells to prevent tires and hooves from catching the geosynthetic material and pulling it up.

Wearing Surface (Running Planks)

On trails managed for equestrian use, snowmobiles, or off-highway vehicles (including ATVs or motorcycles), installing a wearing surface (often called running planks when timber planks are used) on top of the deck planks is strongly recommended to protect the transverse decking from surface wear. It is easier to replace running planks, which are inexpensive, untreated, and often local timber, than it is to replace the preservative-treated, structural-grade decking planks on most structures.

Rub Rails

Installing rub rails at the height of the center of wheels of the design vehicle can provide protection for the railing system and superstructure trusses from impact from tires (figure 17).

Figure 17—Rub rails installed on an aluminum side truss bridge to protect the railing system.

Inspection and Maintenance

Routine inspections and annual maintenance are two other important components of a good trail bridge program. A qualified trail bridge inspector must inspect trail bridges on National Forest System trails at least every 5 years, per FSH 7709.56b, Section 100. Inspections are important for ensuring that bridges are safe for public use and for detecting emerging bridge problems early, before they become significant issues.

Preventative maintenance increases the longevity of a structure, so scheduling annual maintenance is important. Fixing a small maintenance item quickly is easier than replacing an entire structure. Preventative maintenance makes good sense, especially with limited maintenance resources available; it saves money in the long run.

Accumulated dirt and debris on or next to structure members may trap moisture and can promote decay. Completing certain routine, preventative maintenance tasks annually or biannually will reduce the chance of decay before it becomes a significant problem. Some of these tasks include:

- Cleaning leaves and dirt from the deck will help reduce the onset of decay in the deck planks.
- Cleaning the tops of sills will help reduce the chance of decay in sills and bearings.
- Cleaning the tops of stringers will help reduce the chance of decay in timber or rust in steel.
- Clearing brush from the approaches and around the bridge will enable air to flow around the bridge, reducing moisture in the surrounding environment and helping to reduce deterioration of the bridge members.
- Replacing broken or decayed decking as early as possible could be a safety issue. Fastening down the deck planks with screws instead of nails helps make replacing the deck faster and easier.
- Repairing streambanks will help reduce the chance of the abutments failing as a result of scour.

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Appendixes

- Appendix A—Trail Bridge Matrix
- Appendix B—Trail Design Parameters
- Appendix C—Trail Bridge Design Report Folders
- Appendix D—Trail Bridge Specification Excerpts from Standard Specifications for Construction of Trails and Trail Bridges on Forest Service Projects

Appendix A—Trail Bridge Matrix

Structure	Definition	Inspection			Data storage
		Inspector requirements	Inspection form	Inspection interval[1]	
Trail Bridge	A trail structure, including supports, erected over a depression or obstruction such as a body of water, a road, a trail, or a railroad that provides a continuous pathway and that has a deck for carrying traffic or other loads. Trail bridges are divided into three categories for inspection purposes: 1. Complex trail bridges; 2. Major trail bridges; and 3. Minor trail bridges.	NA	NA	NA	Infra Trail Bridges Module
Complex Trail Bridge	Any truss, suspension, or multi-span trail bridge; any trail bridge whose major load carrying elements[2] are not constructed of wood, regardless of width, span, or height; or any major trail bridge determined by the trail bridge inspection program manager to have increased design complexity, user or inspector risk, or decay or damage.	Requires a technical inspection by a person who: 1. Meets bridge inspection team leader requirements per the NBIS; and 2. Is certified by the Regional Director of Engineering.	Complex and Major Trail Bridge Inspection Form	60 months.[1]	Infra Trail Bridges Module
Major Trail Bridge	Any trail bridge with major load carrying elements constructed of wood that has a clear span[3] greater than 20 feet and that is not a complex trail bridge; or any minor trail bridge determined by the trail bridge inspection program manager to have increased design complexity, user or inspector risk, or decay or damage.	Requires a technical inspection by a person who: 1. Has successfully completed the National Trail Bridge Inspection Training; and 2. Is certified by the Regional Director of Engineering.	Complex and Major Trail Bridge Inspection Form (applicable sections)	60 months.[1]	Infra Trail Bridges Module

Structure	Definition	Inspection			Data storage
		Inspector requirements	Inspection form	Inspection interval[1]	
Minor Trail Bridge	Any trail bridge that is not a complex or major trail bridge.	Requires a condition assessment by a person qualified to perform TRACS.	TRACS Minor Trail Bridge Condition Assessment Form	Refer to current agency protocols.	Infra Trail Bridges Module
Other Engineered Trail Structure	A structure such as a fishing dock, elevated viewing platform, elevated boardwalk greater than 4 feet high,[4] retaining wall greater than 6 feet high,[5] or other engineered structure located on or adjacent to an NFS trail and that requires a certain level of technical expertise for design and inspection based on design complexity and potential user or inspector risk.	Depending on the structure, requires a technical inspection by a person qualified to inspect complex or major trail bridges or a condition assessment by a person qualified to perform TRACS, as deemed appropriate by the forest supervisor in consultation with the trail bridge inspection program manager.	Trail Bridge Inspection Form (applicable sections) or TRACS Form	60 months[1] for complex and major trail bridges. Refer to current agency protocols for minor trail bridges.	Infra Trail Bridge Module and Infra Trails Module
Trail Structure	A constructed feature on a trail, such as a boardwalk, puncheon, or a retaining wall no more than 6 feet high.[5] See the Trail Data Dictionary for further information on identification of trail structures.	Requires a condition assessment by a person qualified to perform TRACS.	TRACS Form	Refer to current agency protocols.	Infra Trails Module

NA = not applicable
NBIS = National Bridge Inspection Standards
TRACS = Trail Assessment and Condition Surveys
NFS = National Forest System

1 A more frequent inspection interval may be appropriate due to the complexity, age, condition, and use of the structure.
2 Main load carrying elements include the stringers or deck.
3 The clear span is measured between abutment faces, along the centerline of the trail.
4 Elevated boardwalk height is measured from the lowest adjacent ground surface to the top of the boardwalk deck.

5 Retaining wall height is measured from the lowest adjacent ground surface to the top of the retaining wall.

Appendix B—Trail Design Parameters

- Hiker/Pedestrian (FSH 2309.18, Section 23.11, Exhibit 01)
- Pack and Saddle (FSH 2309.18, Section 23.12, Exhibit 01)
- Bicycle (FSH 2309.18, Section 23.13, Exhibit 01)
- Motorcycle (FSH 2309.18, Section 23.21, Exhibit 01)
- All-Terrain Vehicle (FSH 2309.18, Section 23.22, Exhibit 01)
- Four-Wheel Drive Vehicle > 50″ (FSH 2309.18, Section 23.23, Exhibit 01)
- Cross-Country Ski (FSH 2309.18, Section 23.31, Exhibit 01)
- Snowshoe (FSH 2309.18, Section 23.32, Exhibit 01)
- Snowmobile (FSH 2309.18, Section 23.33, Exhibit 01)

Trail Design Parameters

Hiker/Pedestrian (FSH 2309.18, Section 23.11, Exhibit 01)

Design parameters are technical guidelines for the survey, design, construction, maintenance, and assessment of National Forest System trails, based on their designed use and trail class and consistent with their management intent.[1] Local deviations from any design parameter may be established based on trail-specific conditions, topography, or other factors, provided that the deviations are consistent with the general intent of the applicable trail class.

Designed Use HIKER/PEDESTRIAN		Trail Class 1	Trail Class 2	Trail Class 3[2]	Trail Class 4[2]	Trail Class 5[2]
Design Tread Width	**Wilderness** (Single Lane)	0″ – 12″	6″ – 18″	12″ – 24″ Exception: may be 36″ – 48″ at steep side slopes	18″ – 24″ Exception: may be 36″ – 48″ at steep side slopes	Not applicable
	Non-Wilderness (Single Lane)	0″ – 12″	6″ – 18″	18″ – 36″	24″ – 60″	36″ – 72″
	Non-Wilderness (Double Lane)	36″	36″	36″ – 60″	48″ – 72″	72″ – 120″
	Structures (Minimum Width)	18″	18″	18″	36″	36″
Design Surface[3]	**Type**	Native, ungraded May be continuously rough	Native, limited grading May be continuously rough	Native, with some onsite borrow or imported material where needed for stabilization and occasional grading Intermittently rough	Native with improved sections of borrow or imported material, and routine grading Minor roughness	Likely imported material, and routine grading Uniform, firm, and stable
	Protrusions	≤ 24″ Likely common and continuous	≤ 6″ May be common and continuous	≤ 3″ May be common, not continuous	≤ 3″ Uncommon, not continuous	No protrusions
	Obstacles (Maximum Height)	24″	14″	10″	8″	No obstacles
Design Grade[3]	**Target Grade**	5% – 25%	5% – 18%	3% – 12%	2% – 10%	2% – 5%
	Short Pitch Maximum	40%	35%	25%	15%	5% FSTAG: 5% – 12%[2]
	Maximum Pitch Density	20% – 40% of trail	20% – 30% of trail	10% – 20% of trail	5% – 20% of trail	0% – 5% of trail

Designed Use HIKER/PEDESTRIAN		Trail Class 1	Trail Class 2	Trail Class 3[2]	Trail Class 4[2]	Trail Class 5[2]
Design Cross Slope	Target Cross Slope	Natural side slope	5% – 20%	5% – 10%	3% – 7%	2% – 3% (or crowned)
	Maximum Cross Slope	Natural side slope	25%	15%	10%	3%
Design Clearing	Height	6′	6′ – 7′	7′ – 8′	8′ – 10′	8′ – 10′
	Width	≥ 24″ Some vegetation may encroach into clearing area	24″ – 48″ Some light vegetation may encroach into clearing area	36″ – 60″	48″ – 72″	60″ – 72″
	Shoulder Clearance	3″ – 6″	6″ – 12″	12″ – 18″	12″ – 18″	12″ – 24″
Design Turn	Radius	No minimum	2′ – 3′	3′ – 6′	4′ – 8′	6′ – 8′

[1] For definitions of design parameter attributes (for example, design tread width and short pitch maximum) see FSH 2309.18, Section 05.

[2] Trail classes 3, 4, and 5, in particular, have the potential to provide accessible passage. If assessing or designing trails for accessibility, refer to the Forest Service Trail Accessibility Guidelines (FSTAG) for more specific technical provisions and tolerances (FSM 2350).

[3] The determination of trail-specific design grade, design surface, and other design parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall sustainability of the trail.

Trail Design Parameters

Pack and Saddle (FSH 2309.18, Section 23.12, Exhibit 01)

Design parameters are technical guidelines for the survey, design, construction, maintenance, and assessment of National Forest System trails, based on their designed use and trail class and consistent with their management intent.[1] Local deviations from any design parameter may be established based on trail-specific conditions, topography, or other factors, provided that the deviations are consistent with the general intent of the applicable trail class.

Designed Use PACK AND SADDLE		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Tread Width	**Wilderness** (Single Lane)	Typically not designed or actively managed for equestrians, although use may be allowed	12″ – 18″ May be up to 48″ along steep side slopes 48″ – 60″ or greater along precipices	18″ – 24″ May be up to 48″ along steep side slopes 48″ – 60″ or greater along precipices	24″ May be up to 48″ along steep side slopes 48″ – 60″ or greater along precipices	Typically not designed or actively managed for equestrians, although use may be allowed
	Non-Wilderness (Single Lane)		12″ – 24″ May be up to 48″ along steep side slopes 48″ – 60″ or greater along precipices	18″ – 48″ 48″ – 60″ or greater along precipices	24″ – 96″ 48″ – 60″ or greater along precipices	
	Non-Wilderness (Double Lane)		60″	60″ – 84″	84″ – 120″	
	Structures (Minimum Width)		Other than bridges: 36″ Bridges without handrails: 60″ Bridges with handrails: 84″ clear width	Other than bridges: 36″ Bridges without handrails: 60″ Bridges with handrails: 84″ clear width	Other than bridges: 36″ Bridges without handrails: 60″ Bridges with handrails: 84″ clear width	
Design Surface[2]	**Type**		Native, with limited grading May be frequently rough	Native, with some onsite borrow or imported material where needed for stabilization and occasional grading Intermittently rough	Native, with improved sections of borrow or imported material and routine grading Minor roughness	
	Protrusions		≤ 6″ May be common and continuous	≤ 3″ May be common, not continuous	≤ 3″ Uncommon, not continuous	
	Obstacles (Maximum Height)		12″	6″	3″	

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Designed Use PACK AND SADDLE		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Grade[2]	Target Grade	Typically not designed or actively managed for equestrians, although use may be allowed	5% – 20%	3% – 12%	2% – 10%	Typically not designed or actively managed for equestrians, although use may be allowed
	Short Pitch Maximum		30%	20%	15%	
	Maximum Pitch Density		15% – 20% of trail	5% – 15% of trail	5% – 10% of trail	
Design Cross Slope	Target Cross Slope		5% – 10%	3% – 5%	0% – 5%	
	Maximum Cross Slope		10%	8%	5%	
Design Clearing	Height		8′ – 10′	10′	10′ – 12′	
	Width		72″ Some light vegetation may encroach into clearing area	72″ – 96″	96″	
	Shoulder Clearance		6″ – 12″ Pack clearance: 36″ x 36″	12″ – 18″ Pack clearance: 36″ x 36″	12″ – 18″ Pack clearance: 36″ x 36″	
Design Turn	Radius		4′ – 5′	5′ – 8′	6′ – 10′	

[1] For definitions of design parameter attributes (for example, design tread width and short pitch maximum) see FSH 2309.18, Section 05.

[2] The determination of trail-specific design grade, design surface, and other design parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall sustainability of the trail.

Trail Design Parameters

Bicycle (FSH 2309.18, Section 23.13, Exhibit 01)

Design parameters are technical guidelines for the survey, design, construction, maintenance, and assessment of National Forest System trails, based on their designed use and trail class and consistent with their management intent.[1] Local deviations from any design parameter may be established based on trail-specific conditions, topography, or other factors, provided that the deviations are consistent with the general intent of the applicable trail class.

Designed Use BICYCLE		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Tread Width	**Single Lane**	6″ – 12″	12″ – 24″	18″ – 36″	24″ – 48″	36″ – 60″
	Double Lane	36″ – 48″	36″ – 48″	36″ – 48″	48″ – 84″	72″ – 120″
	Structures (Minimum Width)	18″	18″	36″	48″	60″
Design Surface[2]	**Type**	Native, ungraded May be continuously rough Sections of soft or unstable tread on grades < 5% may be common and continuous	Native, with limited grading May be continuously rough Sections of soft or unstable tread on grades < 5% may be common	Native, with some onsite borrow or imported material where needed for stabilization and occasional grading Intermittently rough Sections of soft or unstable tread on grades < 5% may be present, but not common	Native, with improved sections of borrow or imported materials and routine grading Stable, with minor roughness	Likely imported material and routine grading Uniform, firm, and stable
	Protrusions	≤ 24″ Likely common and continuous	≤ 6″ May be common and continuous	≤ 3″ May be common, but not continuous	≤ 3″ Uncommon and not continuous	No protrusions
	Obstacles (Maximum Height)	24″	12″	10″	8″	No obstacles
Design Grade[2]	**Target Grade**	5% – 20%	5% – 12%	3% – 10%	2% – 8%	2% – 5%
	Short Pitch Maximum	30% 50% on downhill segments only	25% 35% on downhill segments only	15%	10%	8%
	Maximum Pitch Density	20% – 30% of trail	10% – 30% of trail	10% – 20% of trail	5% – 10% of trail	0% – 5% of trail

Designed Use BICYCLE		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Cross Slope	Target Cross Slope	5% – 10%	5% – 8%	3% – 8%	3% – 5%	2% – 3%
	Maximum Cross Slope	10%	10%	8%	5%	5%
Design Clearing	Height	6′	6′ – 8′	8′	8′ – 9′	8′ – 9′
	Width	24″ – 36″ Some vegetation may encroach into clearing area	36″ – 48″ Some light vegetation may encroach into clearing area	60″ – 72″	72″ – 96″	72″ – 96″
	Shoulder Clearance	0″ – 12″	6″ – 12″	6″ – 12″	6″ – 18″	12″ – 18″
Design Turn	Radius	2′ – 3′	3′ – 6′	4′ – 8′	8′ – 10′	8′ – 12′

[1] For definitions of design parameter attributes (for example, design tread width and short pitch maximum) see FSH 2309.18, Section 05.
[2] The determination of trail-specific design grade, design surface, and other design parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall sustainability of the trail.

Trail Design Parameters

Motorcycle (FSH 2309.18, Section 23.21, Exhibit 01)

Design parameters are technical guidelines for the survey, design, construction, maintenance, and assessment of National Forest System trails, based on their designed use and trail class and consistent with their management intent.[1] Local deviations from any design parameter may be established based on trail-specific conditions, topography, or other factors, provided that the deviations are consistent with the general intent of the applicable trail class.

Designed Use MOTORCYCLE		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Tread Width	Single Lane	Typically not designed or actively managed for motorcycles, although use may be allowed	8″ – 24″	18″ – 36″	24″ – 48″	Typically not designed or actively managed for motorcycles, although use may be allowed
	Double Lane		48″	48″ – 60″	60″ – 72″	
	Structures (Minimum Width)		36″	48″	48″	
Design Surface[2]	Type		Native, with limited grading May be continuously rough Sections of soft or unstable tread on grades < 5% may be common and continuous	Native, with some onsite borrow or imported material where needed for stabilization and occasional grading Intermittently rough Sections of soft or unstable tread on grades < 5% may be present	Native, with imported materials for tread stabilization likely and routine grading Minor roughness Sections of soft tread not common	
	Protrusions		≤ 6″ May be common and continuous	≤ 3″ May be common, but not continuous	≤ 3″ Uncommon and not continuous	
	Obstacles (Maximum Height)		18″ May be common or placed for increased challenge	12″ Common and left for increased challenge	3″ Uncommon	
Design Grade[2]	Target Grade		10% – 25%	5% – 20%	3% – 10%	
	Short Pitch Maximum		40%	25%	15%	
	Maximum Pitch Density		20% – 40% of trail	15% – 30% of trail	10% – 20% of trail	

Designed Use MOTORCYCLE		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Cross Slope	Target Cross Slope	Typically not designed or actively managed for motorcycles, although use may be allowed	5% – 10%	5% – 8%	3% – 5%	Typically not designed or actively managed for motorcycles, although use may be allowed
	Maximum Cross Slope		15%	10%	10%	
Design Clearing	Height		6′ – 7′	6′ – 8′	8′ – 10′	
	Width (On steep side hills, increase clearing on uphill side by 6″ – 12″)		36″ – 48″ Some light vegetation may encroach into clearing area	48″ – 60″	60″ – 72″	
	Shoulder Clearance		6″ – 12″	12″ – 18″	12″ – 24″	
Design Turn	Radius		3′ – 4′	4′ – 6′	5′ – 8′	

[1] For definitions of design parameter attributes (for example, design tread width and short pitch maximum) see FSH 2309.18, Section 05.
[2] The determination of trail-specific design grade, design surface, and other design parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall sustainability of the trail.

Trail Design Parameters

All-Terrain Vehicle (FSH 2309.18, Section 23.22, Exhibit 01)

Design parameters are technical guidelines for the survey, design, construction, maintenance, and assessment of National Forest System trails, based on their designed use and trail class and consistent with their management intent.[1] Local deviations from any design parameter may be established based on trail-specific conditions, topography, or other factors, provided that the deviations are consistent with the general intent of the applicable trail class.

Designed Use ALL-TERRAIN VEHICLE		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Tread Width	**Single Lane**	Typically not designed or actively managed for ATVs, although use may be allowed	48″ – 60″	60″	60″ – 72″	Typically not designed or actively managed for ATVs, although use may be allowed
	Double Lane		96″	96″ – 108″	96″ – 120″	
	Structures (Minimum Width)		60″	60″	60″	
Design Surface[2]	**Type**		Native, with limited grading May be continuously rough Sections of soft or unstable tread on grades < 5% may be common and continuous	Native, with some onsite borrow or imported material where needed for stabilization and occasional grading Intermittently rough Sections of soft or unstable tread on grades < 5% may be present	Native, with imported materials for tread stabilization likely and routine grading Minor roughness Sections of soft tread uncommon	
	Protrusions		≤ 6″ May be common and continuous	≤ 3″ May be common, but not continuous	≤ 3″ Uncommon and not continuous	
	Obstacles (Maximum Height)		12″ May be common or placed for increased challenge	6″ May be common and left for increased challenge	3″ Uncommon	
Design Grade[2]	**Target Grade**		10% – 25%	5% – 15%	3% – 10%	
	Short Pitch Maximum		35%	25%	15%	
	Maximum Pitch Density		20% – 40% of trail	15% – 30% of trail	10% – 20% of trail	

Designed Use ALL-TERRAIN VEHICLE		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Cross Slope	**Target Cross Slope**	Typically not designed or actively managed for ATVs, although use may be allowed	5% – 10%	3% – 8%	3% – 5%	Typically not designed or actively managed for ATVs, although use may be allowed
	Maximum Cross Slope		15%	10%	8%	
Design Clearing	**Height**		6′ – 7′	6′ – 8′	8′ – 10′	
	Width (On steep side hills, increase clearing on uphill side by 6″ – 12″)		60″ Some light vegetation may encroach into clearing area	60″ – 72″	72″ – 96″	
	Shoulder Clearance		0″ – 6″	6″ – 12″	12″ – 18″	
Design Turn	**Radius**		6′ – 8′	8′ – 10′	8′ – 12′	

[1] For definitions of design parameter attributes (for example, design tread width and short pitch maximum) see FSH 2309.18, Section 05.
[2] The determination of trail-specific design grade, design surface, and other design parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall sustainability of the trail.

Trail Design Parameters

Four-Wheel Drive Vehicle > 50″ (FSH 2309.18, Section 23.23, Exhibit 01)

Design parameters are technical guidelines for the survey, design, construction, maintenance, and assessment of National Forest System trails, based on their designed use and trail class and consistent with their management intent.[1] Local deviations from any design parameter may be established based on trail-specific conditions, topography, or other factors, provided that the deviations are consistent with the general intent of the applicable trail class.

Designed Use FOUR-WHEEL DRIVE VEHICLE > 50″		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Tread Width	**Single Lane**	Typically not designed or actively managed for 4WD vehicles > 50″, although use may be allowed	72″ – 84″	72″ – 96″	96″ – 120″	Typically not designed or actively managed for 4WD vehicles > 50″, although use may be allowed
	Double Lane		16′	16′	16′	
	Structures (Minimum Width)		96″	96″	96″	
Design Surface[2]	**Type**		Native, with limited grading May be continuously rough Sections of soft or unstable tread on grades < 5% may be common and continuous	Native, with some on-site borrow or imported material where needed for stabilization and occasional grading Intermittently rough Sections of soft or unstable tread on grades < 5% may be present	Native, with imported materials for tread stabilization likely and routine grading Minor roughness Sections of soft tread uncommon	
	Protrusions		≤ 12″ May be common and continuous	≤ 8″ May be common and continuous	≤ 4″ May be common and continuous	
	Obstacles (Maximum Height)		36″ May be common or placed for increased challenge	24″ Common and left for increased challenge	12″ Uncommon	
Design Grade[2]	**Target Grade**		10% – 21%	5% – 18%	5% – 12%	
	Short Pitch Maximum		25%	20%	15%	
	Maximum Pitch Density		20% – 30% of trail	10% – 20% of trail	5% – 10% of trail	

Designed Use FOUR-WHEEL DRIVE VEHICLE > 50″		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Cross Slope	Target Cross Slope	Typically not designed or actively managed for 4WD vehicles > 50″, although use may be allowed	8% – 15%	5% – 12%	5% – 8%	Typically not designed or actively managed for 4WD vehicles > 50″, although use may be allowed
	Maximum Cross Slope		15%	12%	8%	
Design Clearing	Height		6′ – 8′	6′ – 8′	8′ – 10′	
	Width		72″ – 84″ Some light vegetation may encroach into clearing area	72″ – 96″	96″ – 144″	
	Shoulder Clearance		0″ – 6″	6″ – 12″	12″ – 18″	
Design Turn	Radius		10′ – 15′	15′ – 20′	20′ – 30′	

1 For definitions of design parameter attributes (for example, design tread width and short pitch maximum see FSH 2309.18, Section 05.

2 The determination of trail-specific design grade, design surface, and other design parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall sustainability of the trail.

Trail Design Parameters
Cross-Country Ski (FSH 2309.18, Section 23.31, Exhibit 01)

Design parameters are technical guidelines for the survey, design, construction, maintenance, and assessment of National Forest System trails, based on their designed use and trail class and consistent with their management intent.[1] Local deviations from any design parameter may be established based on trail-specific conditions, topography, or other factors, provided that the deviations are consistent with the general intent of the applicable trail class.

Designed Use CROSS-COUNTRY SKI		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Tread Width	**Single Lane**	Typically not designed or actively managed for cross-country skiing, although use may be allowed	2′ – 4′ Typically not groomed	6′ – 8′ Or width of grooming equipment	8′– 10′ Or width of grooming equipment	Typically not designed or actively managed for cross-country skiing, although use may be allowed
	Double Lane		6′ – 8′	8′ – 12′	12′ – 16′	
	Structures (Minimum Width)		36″	36″	36″	
Design Surface[2]	**Type**		Generally no machine grooming	May receive occasional machine grooming for snow compaction and track setting	Regular machine grooming for snow compaction and track setting	
	Protrusions		No protrusions	No protrusions	No protrusions	
	Obstacles (Maximum Height)		12″ Uncommon	8″ Uncommon (no obstacles if machine groomed)	No obstacles	
Design Grade[2]	**Target Grade**		5% – 15%	2% – 10%	0% – 8%	
	Short Pitch Maximum		25%	20%	12%	
	Maximum Pitch Density		10% – 20% of trail	5% – 15% of trail	0% – 10% of trail	
Design Cross Slope	**Target Cross Slope**		0% – 10%	0% – 5%	0% – 5%	
	Maximum Cross Slope (For up to 50″)		20%	15%	10%	

Designed Use CROSS-COUNTRY SKI		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Clearing	**Height** (Above normal maximum snow level)	Typically not designed or actively managed for cross-country skiing, although use may be allowed	6′ – 8′	8′ Or height of grooming equipment	8′ – 10′	Typically not designed or actively managed for cross-country skiing, although use may be allowed
	Width		24″ – 60″ Light vegetation may encroach into clearing area	72″ – 120″ Light vegetation may encroach into clearing area	96″ – 168″ Widen clearing at turns or if increased sight distance needed	
	Shoulder Clearance		0″ – 6″	0″ – 12″	0″ – 24″	
Design Turn	**Radius**		8′ – 10′	15′ – 20′ Or to accommodate grooming equipment	≥ 25′	

[1] For definitions of design parameter attributes (for example, design tread width and short pitch maximum) see FSH 2309.18, Section 05.
[2] The determination of trail-specific design grade, design surface, and other design parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall sustainability of the trail.

Trail Design Parameters

Snowshoe (FSH 2309.18, Section 23.32, Exhibit 01)

Design parameters are technical guidelines for the survey, design, construction, maintenance, and assessment of National Forest System trails, based on their designed use and trail class and consistent with their management intent.[1] Local deviations from any design parameter may be established based on trail-specific conditions, topography, or other factors, provided that the deviations are consistent with the general intent of the applicable trail class.

Designed Use SNOWSHOE		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Tread Width	Single Lane	Typically not designed or actively managed for snowshoe, although use may be allowed	36″	36″ – 48″	36″ – 60″	Typically not designed or actively managed for snowshoe, although use may be allowed
	Double Lane		60″	72″	72″ – 96″	
	Structures (Minimum Width)		36″	48″	48″	
Design Surface[2]	Type		Generally no machine grooming	May receive occasional machine grooming for snow compaction	Likely to receive occasional machine grooming for snow compaction	
	Protrusions		No protrusions	No protrusions	No protrusions	
	Obstacles (Maximum Height)		12″ Uncommon	8″ Uncommon (no obstacles if machine groomed)	No obstacles	
Design Grade[2]	Target Grade		10% – 20%	5% – 15%	0% – 10%	
	Short Pitch Maximum		30%	20%	15%	
	Maximum Pitch Density		5% – 20% of trail	5% – 25% of trail	0% – 10% of trail	
Design Cross Slope	Target Cross Slope		0% – 10%	0% – 5%	0% – 5%	
	Maximum Cross Slope		20%	15%	10%	

Designed Use SNOWSHOE		**Trail Class 1**	**Trail Class 2**	**Trail Class 3**	**Trail Class 4**	**Trail Class 5**
Design Clearing	**Height** (Above normal maximum snow level)	Typically not designed or actively managed for snowshoe, although use may be allowed	6′ – 8′	8′	8′ – 10′	Typically not designed or actively managed for snowshoe, although use may be allowed
	Width		48″ Some light vegetation may encroach into clearing area	72″ Light vegetation may encroach into clearing area	72″ – 96″	
	Shoulder Clearance		0″	12″	12″ – 24″	
Design Turn	**Radius**		3′ – 4′	3′ – 6′	4′ – 8′ Or to accommodate grooming equipment	

[1] For definitions of design parameter attributes (for example, design tread width and short pitch maximum) see FSH 2309.18, Section 05.
[2] The determination of trail-specific design grade, design surface, and other design parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall sustainability of the trail.

Trail Design Parameters

Snowmobile (FSH 2309.18, Section 23.33, Exhibit 01)

Design parameters are technical guidelines for the survey, design, construction, maintenance, and assessment of National Forest System trails, based on their designed use and trail class and consistent with their management intent.[1] Local deviations from any design parameter may be established based on trail-specific conditions, topography, or other factors, provided that the deviations are consistent with the general intent of the applicable trail class.

Designed Use SNOWMOBILE		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Tread Width	Single Lane	Typically not designed or actively managed for snowmobiles, although use may be allowed	4′ – 6′ Typically not groomed	6′ – 8′ Or width of grooming equipment On turns with tight radius, increase groomed width to ≥ 10′	8′ – 10′ Or minimum width of grooming equipment On turns with tight radius, increase groomed width to ≥ 12′	Typically not designed or actively managed for snowmobiles, although use may be allowed
	Double Lane		10′ Typically not groomed	10′ – 12′	12′ – 20′	
	Structures (Minimum Width)		6′	12′	18′	
Design Surface[2]	Type		Generally no machine grooming Commonly rough and bumpy	May receive occasional machine grooming for snow compaction and conditioning Frequently rough and bumpy	Regular machine grooming for snow compaction and conditioning Commonly smooth	
	Protrusions		No protrusions	No protrusions	No protrusions	
	Obstacles (Maximum Height)		12″ Uncommon	6″ Uncommon (no obstacles if machine groomed)	No obstacles	
Design Grade[2]	Target Grade		0% – 12%	0% – 10%	0% – 8%	
	Short Pitch Maximum		35%	25%	20%	
	Maximum Pitch Density		15% – 30% of trail	10% – 20% of trail	5% – 10% of trail	

Designed Use SNOWMOBILE		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Cross Slope	Target Cross Slope	Typically not designed or actively managed for snowmobiles, although use may be allowed	0% – 10%	0% – 5%	0%	Typically not designed or actively managed for snowmobiles, although use may be allowed
	Maximum Cross Slope		15%	10%	5%	
Design Clearing	Height (Above normal maximum snow level)		6′	6′ – 8′ Provide sufficient clearance for grooming equipment	8′ – 12′ Provide sufficient clearance for grooming equipment	
	Width		6′ – 12′ Some light vegetation may encroach into clearing area	8′ – 14 ′ Light vegetation may encroach into clearing area	10′ – 22′ Widen clearing at turns or if increased sight distance needed	
	Shoulder Clearance		6″ – 12″	12″ – 18″	12″ – 24″	
Design Turn	Radius		8′ – 10′	15′ – 20′ Or sufficient radius for grooming equipment	25′ – 50′	

[1] For definitions of design parameter attributes (for example, design tread width and short pitch maximum) see FSH 2309.18, Section 05.
[2] The determination of trail-specific design grade, design surface, and other design parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall sustainability of the trail.

Appendix C—Example of Trail Bridge Design Folder

The following outline shows one way to set up a trail bridge design folder.

Section 1—General Information

- Executive Summary
- Aerial Photographs
- Quad Map
- Photographs
- Environmental Assessment
- Other Information

Section 2—Topographical Survey

- Topographical Survey Map
- Survey Notes
- Survey Photographs
- Other Survey Information

Section 3—Hydrology and Hydraulics

- Stream Classification
- Basin Area Map
- Infrared Photographs
- Regression Calculation for Flow
- Hydraulic Survey
- Hydraulic Analysis
- Hydraulic Recommendations

Section 4—Geotechnical Investigation/Substructure

- Soil Classification
- Soil Investigation
- Foundation Recommendations
- Description of Additional Geotechnical Investigations Required

Section 5—Structural Design/Superstructure

- Design Criteria (See FSH 7709.56b–Transportation Structures Handbook, Chapter 7–Structural Design, section 7.6–Trail Bridges)
    - Loads
        - ◊ Snow—300 pounds per square foot (lb/ft^2) minimum
        - ◊ Vehicle—18,000 lb. Groomer
        - ◊ Wind—90 mph minimum
        - ◊ Combinations
    - Width—See section 7.61 and the Trail Bridge Design Criteria table
    - Length—See Hydrology and Hydraulics
- Sample Calculations for Bridge Superstructure
- Standard Plans To Utilize
- Special Project Specifications for Prefabricated Bridges
- Superstructure Recommendations

Section 6—Cost Estimate/Permits/Other Information

- Cost Estimate
- Permits
- Special Requirements—Timing, Helicopter, Etc.
- Alternative Sites To Consider
- Other Miscellaneous Information

Appendix D—Trail Bridge Specification Excerpts From Standard Specifications for Construction of Trails and Trail Bridges on Forest Service Projects

Section 964 - Prefabricated Steel Trail Bridges

964.00.01 This work consists of designing, furnishing, fabricating, and constructing prefabricated steel trail bridges, including all required materials, hardware, sills, backwalls, rail systems, curbs, decking, excavation, backfill, and approach fills as SHOWN ON THE PLANS. Work includes all other incidental work necessary to complete the bridge installation. These specifications are for a fully engineered clear span bridge and shall be regarded as minimum standards for design and construction.

Design

964.00.02 Engineering Requirements. Structural design of the bridge structure(s) shall be performed by or under the direct supervision of a licensed professional engineer and done in accordance with recognized engineering practices and principles. The engineer shall be licensed to practice in the State in which the bridge is fabricated. The design shall be in accordance with AASHTO LRFD Bridge Design Specifications, Current Edition and as recommended in AASHTO's LRFD Guide Specifications for Design of Pedestrian Bridges, Current Edition. The design shall meet the following requirements unless otherwise SHOWN ON THE PLANS:

1. Pedestrian Load – Main supporting members shall be designed for a pedestrian live load of 90 lb/ft^2.
2. Vehicle Load – When the clear deck width between railings is greater than 7 ft and less than 10 ft, the bridge shall be designed for an occasional single maintenance vehicle of 10,000 lbs (H5 Design Vehicle). When clear deck width is greater than 10 feet, the bridge shall be designed for an occasional single maintenance vehicle of 20,000 lbs (H10 Design Vehicle). The vehicle load shall not be placed in combination with the pedestrian live load or snow load. A vehicle impact allowance is not required.
3. Other Loads – Other loads such as snow, equestrian, wind and fatigue loads, and load combinations shall be designed for as specified in AASHTO LRFD and as SHOWN ON THE PLANS. When a snow load greater than the 90 lb/ft^2 pedestrian load is SHOWN ON THE PLANS the bridge shall be analyzed and designed for the controlling load.
4. Deflection – Pedestrian live load deflection shall not exceed L/360 for steel or as SHOWN ON THE PLANS.
5. Vibration – The fundamental frequency of the pedestrian bridge without live load shall be greater than 3.0 hertz in the vertical direction and 1.3 hertz in the lateral direction for steel bridges. The minimum fundamental frequency for loads other than pedestrian loads such as equestrian and mule trains shall be determined by the design engineer.
6. Camber – The bridge shall have a vertical camber dimension at midspan equal to 100% of the full dead load deflection plus 1% of the full length of the bridge or as SHOWN ON THE PLANS.

964.00.03 General Features of Design. The following are the required minimum design features unless otherwise SHOWN ON THE PLANS.

1. Span – The required bridge span shall be as SHOWN ON THE PLANS.
2. Deck Width – The required bridge width between railing elements as SHOWN ON THE PLANS.

3. Truss Type – Bridge(s) shall be designed as a through (or box) "Pratt" truss with one (1) diagonal per panel and square end vertical members.
4. Through truss bridges will be designed utilizing underhung floor beams.
5. The top of the top chord shall not be less than 42 inches above the deck (measured from the high point of the riding surface) unless otherwise SHOWN ON THE PLANS.
6. Safety Rails – Horizontal safety rails shall be placed on the structure so as to prevent a 4-inch sphere from passing through the truss or as SHOWN ON THE PLANS. The safety rail system shall be designed for 50 pounds per linear foot transversely and vertically, acting simultaneously on each rail.

964.00.04 Design Drawings and Calculations. Provide design drawings and calculations for the prefabricated bridge including wind, seismic, and bearing forces. The Contractor is responsible for preparing all shop drawings necessary for erection of the bridge. All design drawings and calculations shall have the signature and seal of a registered professional engineer.

The Contractor shall submit all design drawings and calculations in accordance with section 903 at least 30 days in advance of the start of fabrication to allow time for review by the contracting officer and correction of any changes. Include plan, elevation, and section views of the pedestrian bridge superstructure, dimensions of all components, connection details, and general and specific notes regarding design and construction.

The Contractor and contracting officer's representative shall be provided with detailed installation instructions.

Materials

964.00.05 Materials. Conform to the following Sections:

Steel Structures	FP-03, Section 00 555
Rock, Grid Pavement Units, and Aggregate	991
Material for Timber Structures	995

Furnish materials that meet the following requirements:

1. Unpainted Steel – Bridges which are not to be painted shall be fabricated from high strength, low alloy, atmospheric corrosion resistant ASTM A847 cold-formed welded square and rectangular tubing and/or ASTM A588, or ASTM A242, ASTM A606 plate and structural steel shapes (Fy = 50,000 psi). The minimum corrosion index of atmospheric corrosion resistant steel, as determined in accordance with ASTM G101, shall be 5.8.
2. Minimum Metal Thickness – The minimum nominal metal thickness of closed structural tubular metal members shall 0.25 inches.
3. 3/8-inch weep holes are required at all low points for bottom and top chords, verticals, and diagonals for closed structural tubular metal members.
4. Hardware – All fasteners and hardware shall be in compliance with FP-03, Section 717 and as SHOWN ON THE PLANS.
5. Wood Decking – Wood decking shall be West Coast Regional Douglas Fir or Southern Pine as SHOWN ON THE PLANS. Treated wood shall meet the requirements as SHOWN ON THE PLANS.

964.00.06 Welding

1. Welding Process – Welding and weld qualification tests shall conform to the provisions of the ANSI/ AWS D1.5 Structural Welding Code.
2. Welders – Welders shall be properly accredited experienced operators, each of whom shall submit certification of satisfactorily passing AWS standard qualification tests for all positions, satisfactory evidence of experience and skill in welding structural steel with the kind of welding to be used in the work, and who has demonstrated the ability to make uniform, sound welds of the type required.

964.00.07 Submittals

1. Welder certifications showing compliance with Section 964.00.06(2)
2. Welding procedures in compliance with Section 964.00.06(1)
3. Steel Certification – All certified mill test reports shall be furnished upon request. Mill test reports shall show the chemical analysis and physical test results for each heat of steel used in the work. All steel shall be produced in the United States of America and be American Institute of Steel Construction certified.
4. Bolt Certification – All certified mill test reports shall be furnished upon request. Mill test reports shall show the chemical analysis and physical test results for each heat of steel used in the work. All bolts shall be produced in the United States of America.
5. Wood Certifications – Furnish the following compliance certificates to the CO upon delivery of the wood materials to the jobsite:
   (a) Verification of compliance with grading rules and species of timber and lumber. Provide certification by an agency accepted as competent by the American Lumber Standards Committee (ALSC).
   (b) Lot certification of each charge for preservative, penetration in inches, and retention in pounds per cubic foot (assay method) by a qualified independent inspection and testing agency. In addition, have the producer of the treated products provide written certification that Best Management Practices (BMPs) in accordance with "Best Management Practices for the Use of Treated Wood in Aquatic and Wetland Environments," published by the Western Wood Preservers Institute (WWPI) and Canadian Institute of Treated Wood, were followed, including a description and appropriate documentation of the applicable BMPs used.
   (c) Such other certifications as SHOWN ON THE PLANS or called for in the SPECIAL PROJECT SPECIFICATIONS.

Provide shop drawings in accordance with section 903 for all bridges 30 days in advance of fabrication when SHOWN ON THE PLANS or in the SPECIAL PROJECT SPECIFICATIONS. Show all dimensions and fabrication details for all cut, framed, or bored timbers.

Construction

964.00.08 General Construct a prefabricated steel trail bridge as required under construction section 964.00. and as SHOWN ON THE PLANS.

964.00.09 Excavation and Embankment. Perform all excavation and embankment work in accordance with Section 911.

964.00.10 Installation. All construction and installation shall be performed in conformance with manufacturer's recommendations and the approved shop drawings. Unprotected steel chains shall not be used as a sling for installation.

964.00.11 Performance. Provide 14 day notice prior to delivery and/or installation of prefabricated bridge.

If the prefabricated superstructure is not installed immediately upon delivery to the project site, provide appropriate equipment and labor to unload and stack, support, and store all material at the delivery point designated by the COR. Support and stack all components to prevent damage. Furnish and install blocking such that all components are supported at least 8 inches above the ground.

Measurement
964.00.12 Measure the section 964 items listed in the bid schedule according to section 906.

Payment
964.00.13 The accepted quantities will be paid at the contract price per unit of measurement for the Section 964 pay items listed in the bid schedule. Payment will be full compensation for the work prescribed in this Section. See Subsection 906.04.

Section 995 – Material for Timber Structures
995.01 Untreated Structural Timber and Lumber. Conform to AASHTO M 168. Furnish an inspection certification from an agency accredited by the American Lumber Standards Committee for the species and grade. Mark all pieces with the inspection service, grade designation, species, and inspector identity.

Season and dry all structural timber and lumber before fabrication. Do not use material that is twisted, curved, or otherwise distorted.

Do not use boxed-heart pieces of Douglas fir or redwood in outside stringers, floor beams, caps, posts, sills, or rail posts. Boxed-heart pieces are defined as timber so sawed that at any point in the length of a sawed piece the pith lies entirely inside the four faces.

Select native log stringers from designated sites on Government-administered land. Select the species and sizes of materials as SHOWN ON THE PLANS. Select native log stringers that are straight, sound, and free of defects. Obtain CO approval of logs and trees before felling or moving them to the site. Fell trees to prevent damage to standing timber and to minimize breakage of trees to be used. Buck logs from felled trees in such a way as to minimize waste and to obtain the required length and diameter.

Peel logs, square the ends, and trim the knots and limbs flush unless otherwise SHOWN ON THE PLANS. Scatter the debris from the processing of timber away from the trail and so it will not block the trail or plug water courses.

Field treat the following untreated timber surfaces in accordance with AWPA standard M4.

(a) All ends and tops, and all contact surfaces of posts, sills, and caps.
(b) All ends, joints, and contact surfaces of bracing and truss members.
(c) All surfaces of timber bumpers and the back faces of bulkheads.
(d) All other timber that will be in contact with earth.
(e) All ends of log stringers.

995.02 Holes for Bolts, Dowels, Rods & Lag Screws. Bore all holes before preservative treating the wood.

Bore holes for round drift bolts and dowels $^{1}/_{16}$ inch smaller in diameter than that of the bolt or dowel to be used. Ensure that the diameter of holes for square drift bolts or dowels is equal to the side dimension of the bolt or dowel.

Bore holes for machine bolts $^{1}/_{16}$ inch larger than the diameter, except when galvanized bolts are specified. In this case, drill all holes $^{1}/_{8}$ inch greater than the bolt size.

Bore holes for lag screws $^{1}/_{16}$ inch larger for the shank portion of the lag screw and drill the remainder of the hole approximately 75 percent of the shank diameter to a depth of 1 inch less than the length of the screw.

995.03 Hardware. Use nails of standard form (ASTM F 1667), wood screws (ANSI/ASME B 18.6.1), hex headed bolts and nuts (ASTM A307), lag screws (ASTM A307 and ANSI/ASME B18.2.1), carriage bolts (ASTM A307), and drift pins and dowels (ASTM A307) as SHOWN ON THE PLANS.

Fabricate washers from gray iron or malleable iron castings unless structural washers are specified. Use malleable iron washers with a diameter approximately four times the bolt diameter under all bolt heads or nuts in contact with wood, unless otherwise SHOWN ON THE PLANS.

Galvanize all hardware according to AASHTO M 232 or cadmium plate all hardware according to ASTM B 766 class 12, type III, unless otherwise SHOWN ON THE PLANS, except for the glued laminated deck panel dowels. Ensure that all fasteners, including nails, spikes, bolts, washers, and timber connectors, other than malleable iron, are galvanized.

Final tighten all nuts to provide proper bearing and snug tight condition. Snug tight is defined as sufficient tightness to bring faces of members into firm contact with each other. Cut off excess bolt lengths of more than 1 inch. After final tightening, check or burr all bolts effectively with a pointing tool to prevent loosening of the nuts.

995.04 Treated Structural Timber and Lumber. Furnish wood according to Subsection 995.01. Incise all wood and make all dimensional cuts and holes in the wood before pressure treatment. Use wood preservative treatment methods meeting the requirements of AASHTO M 133 as SHOWN ON THE PLANS. Treat dimensional lumber, sawn timber and glued laminated timber members according to AWPA Standards as SHOWN ON THE PLANS.

All treated stringers, decking, running planks, and handrails shall be treated after fabrication in accordance with AWPA U1, *Use Category System*, using Pentachlorophenol or Copper Naphthenate (CuN) in Light Oil, (Type C Solvent) for Use Category UC3B.

All treated substructures (sills, backing planks, cribs, timber walls, etc.) shall be treated after fabrication in accordance with AWPA U1 *Use Category System*, using Pentachlorophenol or Copper Naphthenate (CuN) in Heavy Oil (Type A Solvent) for Use Category UC4B.

Treated timber members shall comply with the requirements of the current edition of WWPI's *Best Management Practices for the Use of Treated Wood in Aquatic and Wetland Environments*.

Except for pine, incise before treatment all surfaces greater than 2 inches in width and all Douglas fir and western larch surfaces. Field treat all cuts, abrasions, drilled holes, and recesses that occur after initial preservative treatment in accordance with the requirements specified in AWPA standard M4, *Standard for the Care of Pressure-Treated Wood Products*. Plug all unused holes with preservative-treated plugs. Perform all field-applied preservation treatment with necessary precautions so as to prevent soil and/or water contamination.

All treated timber members must have an approved American Lumber Standards Committee quality mark, individually or sealed pallets, assuring that treatment conforms to the appropriate AWPA standards.

Submit a certified copy of the lot certification, by a qualified independent inspection and testing agency, to the CO for each charge of preservative, stating penetration in inches and retention in pounds per cubic foot (assay method). In addition, provide a written certification from the producer of the treated products that "*Best Management Practices for the Use of Treated Wood in Aquatic and Wetland Environments*," published by the Western Wood Preservers Institute and Canadian Institute of Treated Wood, were utilized. Include a description and appropriate documentation of the Best Management Practices used.

Handle treated timber according to the Consumer Information Sheet published by AWPA. Do not cut, frame, or bore treated timber after treatment unless approved by the CO. Handle treated timbers carefully and do not drop, damage outer fibers, or penetrate the surface with tools. Do not use cant dogs, hooks, or pike poles. In coastal waters, do not cut or bore timber below the highwater mark.

995.05 Structural Glued Laminated Timber. Furnish structural glued laminated timber according to American National Standard, "Standard Specifications for Structural Glued Laminated Timber of Softwood Species" (ANSI 117). Fabricate according to the combination and grade as indicated in the contract. Fabricate structural glued laminated members according to American National Standard, "Standard for Wood Products – Structural Glued Laminated Timber" (ANSI A190.1).

Manufacture members as industrial appearance grade for wet use conditions, using a phenol-resorcinol resin type of adhesive throughout. Use only single- or multiple-piece laminations with bonded edge joints.

About NTDP

The U.S. Department of Agriculture, Forest Service, National Technology and Development Program provides Forest Service employees and partners with practical, science-based solutions to resource management challenges. We evaluate, design, and develop new technologies, products, and systems to solve problems and deliver solutions.

About the Author

James Scott Groenier is a professional engineer who began working for the National Technology and Development Program (NTDP) as a project leader in 2003. Groenier earned a bachelor's degree in civil and environmental engineering from the University of Wisconsin at Madison and a master's degree in civil engineering from Montana State University. He worked for the Wisconsin and Illinois State Departments of Transportation and with an engineering consulting firm before joining the Forest Service in 1992. Before joining NTDP, Groenier worked as the east zone structural engineer for the Eastern Region and as a civil engineer for the Ashley and Tongass National Forests. He is the now the Multi-Regional Bridge Inspection Program Manager for regions 1, 2, 3, and 4.

Library Card

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The Forest Service manages more than 157,000 miles of trails and more than 6,700 trail bridges. Designing trail bridges based on trail-specific TMOs is essential for providing the desired trail experience, for ensuring user safety, and for maximizing bridge longevity. Managing a trail bridge for sustainability requires proper siting, good design details, routine inspections, and maintenance. This report focuses on designing new, short, single-span, wooden trail bridges that the Forest Service classifies as minor and major trail bridges and briefly discusses prefabricated steel bridges.

Keywords: trail bridge construction, trail bridge design, trail bridge inspection, trail bridge maintenance, trail bridge materials, trail bridge plans and specifications, trail bridge siting, trail bridge structure, trail bridge types

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