11. Structural Systems and Dimensions

11.1. Introduction

Chapter 4 discusses the importance of bridge type selection and the content and format of the Bridge Type Selection Report. Chapter 11 discusses the type selection of the major components of the bridge (i.e., superstructure, substructure, foundation), and this chapter discusses other factors that impact these decisions (e.g., hydraulics, roadway design elements). In general, the chapter has been organized to present the decision-making process from the location of the bridge to the structure-type selection for the site.

11.1.1. Alaska-Specific Issues

The AASHTO *LRFD Bridge Design Specifications* are intended for general application nationwide. When compared to the contiguous United States, however, the state of Alaska presents challenges to bridge design, construction, and maintenance due to the extreme climate, rugged terrain, and a generally remote location. Therefore, some flexibility in the application of the *LRFD Specifications* is necessary to account for these challenges. Consider the issues outlined below when consulting this chapter.

1. **Construction:** The short construction season in Alaska, due to the cold climate, favors accelerated bridge construction (ABC) techniques. Further, DOT&PF prefers designs that do not require two or more construction seasons. Bridge construction sites can be very remote dictating a preference for pre-fabricated components of modest proportions.

2. **Availability of Construction Materials:** Depending upon the location within the state, contractors must transport a significant portion of the bridge materials long distances to the bridge site. Few or no local construction materials and fabricated bridge components may be available. In many cases, fabricated bridge components must be shipped from the contiguous US.

3. **Design:** Seasonal climate extremes can result in large design temperature ranges. These temperature ranges dictate a preference for certain bridge or component types.

4. **Maintenance:** Due to access issues for remote sites, DOT&PF prefers bridges requiring little or no maintenance. Life-cycle cost considerations justify higher initial costs, such as metalizing steel bridges to reduce maintenance costs.

5. **Environmental Considerations:** The environmental impacts from proposed highway and bridge projects in Alaska can be an especially sensitive issue and may involve unique design constraints.

6. **Construction Costs:** Ultimately, all of the preceding factors impact bridge construction costs.

   Initial costs for bridges in Alaska may be higher than in the contiguous US; however, life-cycle cost considerations suggest that Alaska bridges are not inordinately more expensive.

Because of the unique issues associated with remote construction sites, Chapter 20 specifically addresses bridge design and construction for these sites.

11.2. Bridge Location

Establishing the location of a bridge is an interactive process among DOT&PF units responsible for roadway design, bridge design, hydraulics, geotechnical engineering, right-of-way, and environment. The process of selecting a bridge location should consider economics, ease of construction, minimizing environmental impacts, and optimizing service for the traveling public.

The DOT&PF regional project managers are responsible for coordinating the activities of the various Department units in selecting the bridge location. Bridge location, in turn, will impact the structure-type selection. This section summarizes the significant factors that impact the decision.

11.2.1. Roadway Design

Roadway design factors that impact bridge location and structure-type selection include the following:

- horizontal alignment (e.g., tangent, curve, superelevation, skew)
- vertical clearances and alignment (e.g., longitudinal gradient, vertical curves)
- traffic volumes
- roadway width
- presence of medians, sidewalks, bike lanes
- clear zones through underpasses

The roadway designer establishes the roadway alignment. Ideally, bridges are located on a tangent alignment with no skew, width changes, or superelevation transitions. However, project constraints may not allow this.

Although bridges can be designed to accommodate almost any given geometry, the bridge engineer must work closely with the roadway designer to minimize the adverse effect of some of the following roadway design issues.

Horizontal Alignment

Where bridges are constructed on horizontal curves, the bridge design, geometry, and construction becomes complicated and the number of feasible bridge types is limited. The structural analysis of horizontally curved bridges with small radii of curvature requires a refined computer analysis.

Hand-calculation methods are available but are accurate only for horizontally curved bridges of large radii. Only use hand calculations as a check of the refined analysis. See Chapter 13 for guidance on acceptable analysis methods.

In general, structural steel and cast-in-place concrete are best suited for horizontally curved bridges.

Decked bulb-tee girders are suited for larger radius curves where the deck curvature can be accommodated by the top flange. Decked girders can also accommodate a limited amount of superelevation transition (e.g., 1 percent change in cross slope).

Skew

Skews of less than approximately 30 degrees are acceptable for most bridge types and result in moderate detailing challenges. Bridges with skews of more than 30 degrees require the Chief Bridge Engineer's approval.

Some structure types with skews more than 30 degrees may require a refined analysis. Analyze all structures with skews of more than 60 degrees by refined methods.

Bridges having a skew of more than 60 degrees may also have long-term functionality problems such as uplifting of girders in the acute corners, lateral translation of the bridge bearings, or both. Consider alternatives to these highly skewed bridges if practical. See Chapter 13 for guidance on acceptable methods for analyzing bridges of varying skew.

Vertical Alignment

Vertical alignment is not typically considered in the structural analysis of bridges; however, vertical alignment is reflected in the calculated camber for steel and precast concrete girders. Most bridges with significant vertical curvature require perpendicular placement of the deck-finishing machine.

All bridges require some elevation change in vertical alignment to allow for deck drainage. Use a minimum of a 0.5 percent longitudinal gradient or a crest vertical curve to accommodate bridge deck drainage.

11.2.2. Hydraulics

The hydraulics engineer will prepare a Hydraulics Report in accordance with the *Alaska Highway Drainage Manual* and provide preliminary hydraulic recommendations in coordination with the Bridge Section's structure-type selection. The critical hydraulic factors may include the following:

- channel geometry
- peak flow discharge
- design water surface elevation(s)
- skew angle
- freeboard requirements, including navigational openings
- scour and erosion potential
- flood plain management objectives
- water-related regulatory requirements

Locate bridges to accommodate natural channel processes and to minimize affects on channel morphology. Many rivers in Alaska are highly dynamic, with complex braid plains and channel networks, high rates of bank erosion and channel migration, and varying flow distributions between channels. Some are subject to glacial outburst floods, ice jams, aufeis accumulation, or other cold region challenges.

The hydraulics engineer and state foundation engineer provide preliminary information to determine the potential for scour at each proposed site.

Spur dikes and other forms of channel control are sometimes needed to ensure favorable flow alignments under bridges. The hydraulics engineer will provide guidance and recommendations regarding the need for these controls.

Responsibilities of Hydraulics Engineer

The hydraulics engineer is responsible for hydrologic and hydraulic analyses for bridge waterway openings. The hydraulics engineer performs the following for the design of bridge waterway openings for bridges:

- hydrologic analysis to determine the design flow rates
- hydraulic analysis to determine the channel geometry and protection provisions needed to meet hydraulic engineering objectives;
- scour analysis for foundation design
- river ice consideration to assess risks of ice jams, aufeis accumulation, or other ice-related processes
- deck drainage analysis to determine the need for deck drains or other stormwater controls. This task is usually performed in coordination with roadway designers, regional hydraulic engineers, bridge engineers, and environmental analysts.

Based on the hydraulic analysis, the hydraulics engineer will provide the following to the bridge engineer for new bridges:

1. water surface elevation(s) for the design peak flow discharge. DOT&PF bridge plans generally include the 2 percent, 1 percent, and 0.2 percent annual exceedence probability discharges.
2. freeboard requirements for ice or debris
3. range of anticipated ice thicknesses along the study reach
4. bridge waterway opening dimensions and skew angle
5. results of the hydraulic scour analysis
6. channel and abutment protection measures

The hydraulics engineer also determines whether the bridge design is consistent with environmental regulations related to hydraulics engineering, such as flood plains.

Hydraulic Definitions

The following presents selected hydraulic definitions that have an application to bridge design:

Annual Exceedence Probability (AEP) Discharge: The term preferred by the scientific community for describing discharge values based upon statistical analysis of streamflow gaging records of annual peaks. A 1 percent AEP discharge is synonymous to the “100-year flood.”

Aufeis: (German for “on ice”) A form of ice accumulation or sheet-like mass of layered ice that forms from successive flows of ground water over an ice surface during freezing temperatures. This form of ice is also commonly referred to as “icings.”

Backwater: The incremental increase in water surface elevation upstream of a highway facility usually associated with a channel encroachment.

Base Flood: The flood having a 1 percent chance of being exceeded in any given year (i.e., the 1 percent AEP discharge and “100-year flood”).

Base Floodplain: The area subject to flooding by the base flood.

Breakup: (of river ice). The downstream transport of ice along rivers and creeks during the seasonal thaw of spring. Spring breakup can also involve ice jams with severe backwater and flooding.

Bridge Waterway Opening: The opening provided in the roadway embankment intended to pass the stream flow under the design conditions.

Design Flood Frequency: The flood frequency selected for determining the necessary size of the bridge waterway opening.

Design Surface Water Elevation: The water elevation produced by the design flood.

Flood Frequency: The number of times a flood of a given magnitude can be expected to occur on average over a long period of time.

Freeboard: The clearance between the design water surface elevation and the low chord of the superstructure.

Ice Jam: A phenomenon of ice accumulation in a channel causing a disruption to the downstream movement of ice and water. Ice jams can cause severe backwater events.

Maximum Allowable Backwater: The maximum amount of backwater that is acceptable to DOT&PF for a proposed facility based on local ordinances, state and federal laws, and on DOT&PF policies.

Ordinary High Water (OHW): The mark along the bank up to which the presence and action of the non-tidal water are so common and usual, and so long continued in all ordinary years, as to leave a natural line impressed on the bank or shore and indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics (see Alaska Statutes 41.17.950(15) for the legal definition). This line shall be located and established during the site topographic survey or location hydraulic survey. The OHW line is a legal boundary and should be surveyed by licensed professional surveyors if needed for boundary control purposes (e.g., property lines, delineations of jurisdictional authority).

Overtopping Flood: That flood event that will overtop the elevation of the bridge or roadway approaches.

Peak Discharge: (Also: Peak Flow or Peak Streamflow.) The maximum volumetric rate of water flow for a given time period. The peak discharge for the 1 percent AEP flood or "100-year flood" is expressed as Q_{100}.

Recurrence Interval: (Also: Return Period). This term refers to the estimated number of years between occurrences of a given discharge, based upon statistical analysis. The recurrence interval is simply the inverse of the Annual Exceedence Probability value. For example, a flood having a 1 percent annual exceedence probability (AEP) would happen, on average, every 100 years (1/0.01 AEP).

Regulatory Floodway: The floodplain area that is reserved in an open manner by federal, state, or local agency requirements (i.e., unconfined or unobstructed either horizontally or vertically) to provide for the discharge of the base flood so that the cumulative increase in water surface elevation is no more than a designated amount as established by the Federal Emergency Management Agency (FEMA) for administering the National Flood Insurance Program (NFIP).

Scour: This term refers to the displacement of soils (including rock) due to flowing water. It is usually used to describe the removal of channel substrate in the vertical direction, whereas "erosion" is the preferred term to describe lateral channel adjustments to flowing water. There are three forms of scour:

1. **Contraction Scour:** Contraction scour, in a natural channel or at a bridge crossing, involves the removal of material from the bed and banks across all or most of the channel width. This component of scour results from a contraction of the flow area at the bridge, which causes an increase in velocity and shear stress on the bed at the bridge. The contraction can be caused by the bridge or from a natural narrowing of the stream channel.
2. **Local Scour:** Removal of material from around piers, abutments, spurs, and embankments caused by an acceleration of flow and resulting vortices induced by obstructions to the flow.
3. **Long-Term Scour:** Aggradation and degradation of the stream bed. These terms refer to the general and progressive buildup (aggradation) or lowering (degradation) of the longitudinal profile of a channel bed due to sediment deposition or removal, respectively. The terms "deposition" and "sedimentation" are often used to describe "aggradation"; "incision" and "head-cutting" are often used to describe "degradation."

Thalweg: The line extending down a channel that follows the lowest elevation of the bed.

Hydraulic Design Criteria

The following summarizes DOT&PF's basic hydraulic criteria used for the design of bridge waterway openings:

1. **Design Flood Frequency**. The hydraulics engineer determines the minimum design flood frequency, which is based on the roadway classification, scour design criteria, flood plain regulations, and ranges from the 50-year event to the 500-year event.
2. **Maximum Allowable Backwater.** On FEMA-delineated floodways, no backwater may be introduced by the structure. On FEMA-delineated floodplains, 1 foot of maximum backwater may be introduced. For all sites, the maximum allowable backwater shall be limited to an amount that will not result in unreasonable damage to upstream property or to the highway. The hydraulics engineer will determine the allowable backwater for each site.
3. **Freeboard**. Establish a specified clearance, generally 3 feet, to allow for passage of debris. Evaluate clearance for the passage of ice or for icing conditions on a case-by-case basis, but is generally 3 feet or greater. Where this is not practical, establish the clearance based on the type of stream and level of protection desired. For navigation channels, establish a vertical clearance conforming to federal requirements based on normally expected flows during the navigation season.
4. **Scour**. The bridge foundation must not fail or be damaged for the scour design event of the 100-year and 500-year flood. Check lesser flood events if there are indications that less frequent events may produce significantly deeper scour than the 100-year flood.
5. **Riprap**. For riverine applications, DOT&PF typical practice is to place riprap to an elevation of not less than 1 foot above the design surface water elevation. If ice is a concern, it may be warranted to place riprap to a higher elevation. For coastal applications, such as shore protection provisions, consult DOT&PF coastal engineers for design support.
6. **Ice**. Consider both static and flowing ice in the hydraulic design.

Costs

Economy of construction is usually a significant consideration in determining spans, pier locations, and orientation. Initial construction costs are always a factor in the structural design of a bridge, but this is only one element of the total economic cost of a stream crossing system. There are hydraulic considerations, maintenance costs, and risks of future costs to repair flood damages that should also be factors in the decision on the number of piers, their location, orientation, and type.

Bridge vs Culvert

In some cases, the waterway opening for a highway-stream crossing can be accommodated by either a culvert or a bridge. Estimates of costs and risks associated with each will indicate which structural alternative should be selected. Figure 11-1 lists some of the advantages and disadvantages of bridges and culverts.

As a general rule of thumb, a design peak discharge of 1000 cfs or less favors a culvert; greater than 1500 cfs favors a bridge. Between 1000 cfs and 1500 cfs, either structure type may be appropriate.

The Statewide Hydraulics Engineer and regional hydraulics engineer will collaborate on the selection.

Abutments

The principal hydraulic concerns for abutments are orientation, extent of channel encroachment, and the need for scour protection provisions. Scour risks can usually be addressed by providing an adequate waterway opening and scour countermeasures. Orientation is usually the same as for adjacent piers.

Piers - Coordination

Locating piers in waterways is an interactive process among the bridge engineer, foundation engineer, and hydraulics engineer.

Initially, the hydraulics engineer determines the required channel geometry to meet the hydraulic criteria (e.g., maximum backwater for 100-year flood).

The bridge engineer determines the number and length of spans, types of piers, and low-chord elevation.

Bridges	
Advantages	**Disadvantages**
• Less susceptible to clogging with drift, ice, and debris. • Waterway increases with rising water surface until water begins to submerge superstructure. • Scour increases waterway opening. • Flowline is flexible. • Minimal impact on aquatic environment and wetlands. • Widening does not usually affect hydraulic capacity.	• Requires more structural maintenance than culverts. • Abutment fill slopes susceptible to erosion and scour damage. • Piers and abutments susceptible to failure from scour. • Susceptible to ice and frost formation on deck. • Bridge railing and parapets hazardous as compared to recovery areas. • Deck drainage may require frequent maintenance cleanout. • Buoyancy, drag, and impact forces are hazards to bridges. • Susceptible to damage from stream meander migration.

Culverts	
Advantages	**Disadvantages**
• More roadside recovery area can be provided. • Grade raises and widening projects sometimes can be accommodated by extending culvert ends. • Requires less structural maintenance than bridges. • Frost and ice usually do not form before other areas experience the same problems. • Capacity increases with stage. • Capacity can sometimes be increased by installing improved inlets. • Usually easier and quicker to build than bridges. • Scour is localized, more predictable, and easier to control. • Storage can be utilized to reduce peak discharge. • Avoids deep bridge foundations.	• Multiple barrel culverts, whose width is considerably wider than the natural approach channel, may silt in and may require periodic cleanout. • No increase in waterway as stage rises above soffit. • Can clog with drift, debris, or ice. • Possible barrier to fish passage. • Susceptible to erosion of fill slopes and scour at outlets. • Susceptible to abrasion and corrosion damage. • Extension may reduce hydraulic capacity. • Inlets of flexible culverts susceptible to failure by buoyancy. • Rigid culverts susceptible to separation at joints. • Susceptible to failure by piping and/or infiltration.

Figure 11-1
Bridge vs. Culvert (Hydraulic Considerations)

The hydraulics engineer evaluates the bridge design proposal to determine if it meets the hydraulic requirements of the waterway opening. For example, to meet the hydraulic criteria, it may be necessary to increase span lengths.

Next, the bridge engineer and foundation engineer evaluate potential foundation designs for the pier and provide preliminary design information to the hydraulics engineer for scour analysis. If the resulting foundation design is judged to be too costly, the bridge engineer will evaluate reducing the number of piers or eliminating piers altogether based on overall structure costs, environmental impacts, constructability, etc.

The highway profile (i.e., vertical alignment and bridge end elevations) is an additional highway design element in the iterative process to identify the number and location of piers in waterways. The profile can have a significant impact on the overall bridge opening and floodplain flow conditions. The roadway designer may prefer, for example, to lower the highway profile due to significant right-of-way impacts which, all other factors being equal, reduces the hydraulic capacity of the waterway opening and increases the frequency of overtopping.

Ultimately, all of these factors (i.e., structural, hydraulic, geotechnical, roadway, environmental, costs) must be evaluated to identify the optimum number and location of piers.

Piers - Hydraulic Design Considerations

Limit the number of piers in any channel to a practical minimum, and avoid piers in the channel of small streams, if practical. The cost of constructing piers increases with the water depth. Piers properly oriented with the flow do not usually contribute significantly to bridge backwater, but they can contribute to scour. Align piers with dominant flow direction at flood stage to reduce floating debris accumulation potential, to reduce the contraction effect of piers in the waterway, to minimize debris forces, and to minimize backwater and scour. Pier orientation is difficult where flow direction changes with stage or time. In this case, consider the use of a single column pier.

Pier shape is also a factor in local scour. Rounding or tapering the leading edges of piers helps to decrease the accumulation of debris and reduces local scour at the pier.

Foundations

The foundation is usually the bridge element that is most vulnerable to flood damage. Examination of boring logs and subsurface material information is important to the prediction of potential scour depths.

Driven piles or drilled shafts usually depend upon the surrounding material for skin friction and lateral stability. In some cases, they can be extended to rock or other dense material for load-carrying capacity through tip resistance. Determine tip elevations for piling or drilled shafts considering estimates of potential scour depths and bearing to avoid losing lateral support and load-carrying capacity during floods.

Consider the potential scour and the possibility of channel shifts in designing foundations for bridges on floodplains and spans approaching the stream channel. Do not consider the thalweg (i.e., the line or path connecting the lowest flow points along the channel bed) to be in a fixed location when establishing founding elevations. The history of a stream and a study of how active it has been can be useful in making decisions on pile and drilled shaft tip elevations.

11.2.3. Geotechnical Engineering

The foundation engineer in the Statewide Material Section provides preliminary foundation information for a proposed site. Bridges located at different sites have different foundation requirements, which must be considered in determining the bridge location.

11.2.4. Right-of-Way

Right-of-way and utilities can have a significant influence on the bridge location and the right-of-way acquisition and utility relocations can require a significant timeframe to complete. The Right-of-Way Section can provide estimates on cost, number of properties and utilities encountered, possible difficult acquisitions, and approximate time frames. In addition to property acquisition, most projects require temporary and permanent easements for construction staging areas, access, future maintenance, and construction.

Right-of-way issues are usually handled through, and coordinated by, the regional project manager, who will typically address right-of-way estimates and impacts. This information, in turn, will assist the bridge engineer in preparing the bridge layout within the right-of-way constraints. Plot the right-of-way lines on the General Layout and Site Plan sheets.

Consider the following right-of-way factors when selecting the structure type:

1. **Expensive Right-of-Way**. If right-of-way will be expensive, this may lead to the use of retaining walls and other measures to reduce right-of-way impacts.
2. **Structure Depth**. The available right-of-way at the bridge site may affect the vertical alignment of the structure which may, in turn, affect the acceptable structure depth to meet the vertical clearance requirements. The depth of the superstructure can be a significant issue in urban areas. Right-of-way acquisition costs are high, and roadway profiles cannot usually be raised due to access rights on approaches.

Bridge designs must be consistent with DOT&PF utility accommodation policies. Chapter 16 discusses utility attachments to bridges.

11.2.5. Environmental

Potential environmental impacts can significantly affect bridge location and structure-type selection and configuration, especially for highway bridges over streams. In general, all bridge projects must attempt to avoid and minimize environmental impacts as practical, especially in sensitive areas (e.g., wetlands, endangered species habitat, essential fish habitat, anadromous or resident fish streams). The DOT&PF regional environmental offices, in coordination with the DOT&PF statewide environmental office, are responsible for identifying all environmental resources and other related issues of concern in the project area and for coordinating with the Bridge Section (through the regional project manager) to evaluate the potential project impacts on these resources and issues. In addition, the regional environmental offices are responsible for ensuring that proposed projects comply with applicable requirements for public involvement. See the *Alaska Environmental Procedures Manual* for a detailed discussion on the environmental process, environmental impact issues and considerations, and environmental permit requirements.

Environmental Class of Action

For every DOT&PF project involving federal funding, authorizations, or approvals, the regional environmental office, in coordination with the statewide environmental office and the FHWA Alaska Division, will determine the Environmental Class of Action (i.e., the level of processing required for compliance with the National Environmental Policy Act [NEPA]). This determination will be based on the results of the evaluation of project impacts and the nature and scope of the proposed project, which will be one of the following:

1. **Categorical Exclusion**. A Categorical Exclusion (CE) is issued for categories of projects that do not individually or cumulatively have a significant effect on the environment and, therefore, do not require the preparation of an EA or EIS.
2. **Environmental Assessment**. An Environmental Assessment (EA) is prepared for projects for which the significance of the environmental impact is not clearly established.
3. **Environmental Impact Statement**. An Environmental Impact Statement (EIS) is prepared for projects where it is known that the action will have a significant effect on the environment.

Permits/Approvals

A proposed bridge project may precipitate the need for one or more environmental permits or approvals. The regional environmental office is responsible for coordinating with the applicable federal or state agency to acquire the applicable permit(s) or approval(s). This may require considerable coordination with the Bridge Section through the regional project manager. The following briefly discuss these permits/approvals.

US Army Corps of Engineers Section 404 Permit. The Section 404 Permit is required for the discharge of dredge or fill material into any waters of the United States, including wetlands. The purpose of Section 404 is to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters through the prevention, reduction, and elimination of pollution.

Section 401 Water Quality Certification. Pursuant to Section 401 of the *Clean Water Act*, the Section 401 Water Quality Certification is issued by the Alaska Department of Environmental Conservation (DEC) based on regulations issued by the US Environmental Protection Agency. The purpose of the Section 401 Certification is to ensure that a permitted discharge will not violate applicable water quality standards. A Section 401 Certification (or waiver of Certification) is required in conjunction with any federal permit (e.g., a Section 404 Permit) to conduct activities that may result in any discharge into waters of the United States.

Section 402 NPDES Permit. Pursuant to Section 402 of the *Clean Water Act*, the Section 402 National Pollutant Discharge Elimination System (NPDES) Permit is issued by DEC based on regulations issued by the US Environmental Protection Agency. The purpose of the Section 402 Permit is to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters through prevention, reduction, and elimination of pollution.

US Coast Guard Section 9 Permit. Pursuant to Section 9 of the *Rivers and Harbors Act* of 1899, the Section 9 Permit is issued by the US Coast Guard. The Section 9 Permit ensures that there will be no interference to navigation on the navigable waterways of the United States. The Permit is required for the construction, modification, replacement, or removal of any bridge or causeway over a navigable waterway. FHWA implementing regulations can be found at 23 CFR 650, Subpart H, Navigational Clearances for Bridges (23 CFR 650.801 and following).

Floodplain Encroachment Approval and Finding. Pursuant to Executive Order 11988 "Floodplain Management," DOT&PF must seek approval from the Federal Emergency Management Agency (FEMA) for any federally funded/regulated project that produces a significant floodplain encroachment. If a project will have a significant floodplain encroachment, the project will require either an Environmental Assessment (EA) or Environmental Impact Statement (EIS). A proposed action that includes a significant floodplain encroachment will not be approved unless FHWA finds (pursuant to 23 CFR650A) that the proposed action is the only practical alternative.

Fish Habitat Permits. Fish habitat permits may be required for DOT&PF construction projects. These permits are issued by the Alaska Department of Fish and Game (ADF&G).

Under the *Fishway Act*, an "840" permit must be obtained for work that may impede the efficient passage of fish. Generally, DOT&PF obtains this permit before placing hydraulic structures in streams with resident fish, but "840" authorization is also required for the following activities:

- stream diversions or realignments,
- low-water crossings, and
- removal of material below ordinary high water (OHW).

Under the *Anadromous Fish Act*, an "870" permit must be obtained for any construction activity within or across a specified anadromous waterbody that would use, divert, pollute, or change the natural flow or bed. Essentially, any construction activity that is below the OHW of a cataloged anadromous fish stream requires an "870" permit.

Special Area Permit. ADF&G administers Alaska Statutes for the protection of State of Alaska Refuges, State Sanctuaries, and State Critical Habitat Areas. These statutes require a "special area permit" from ADF&G for any habitat-altering work, including construction activity, in a designated state refuge, sanctuary, or critical habitat area.

Fish and Wildlife Coordination Act Consultation. This Act requires consultation with the US Fish and Wildlife Service (USFWS) and state fish and wildlife agencies where the "waters of any stream or other body of water are proposed or authorized, permitted, or licensed to be impounded, diverted, or otherwise controlled or modified" by any agency under a federal permit or license. The purpose of consultation is for "preventing loss of and damage to wildlife resources."

Hazardous Waste

The regional environmental offices are responsible for identifying and evaluating hazardous waste sites and for determining the needed mitigation measures. Four specific types of hazardous waste that may require treatment for a bridge project include:

1. **Paint Removal**. Removal of paint from steel bridges that may contain heavy metals or from concrete bridges that may contain asbestos.
2. **Fine Surface Finish**. This type of concrete finish may contain asbestos.
3. **Timber Removal**. Salvaging or disposing of treated timber from an existing bridge.
4. **Plates**. Asbestos blast plates on railroad overpasses.

11.3. Span Length and Configuration

The total required length of a bridge is usually fairly easy to determine. Determining the optimum number of spans can be more difficult. This depends upon the:

- roadway profiles;
- vertical clearances;
- construction requirements (e.g., river diversions, falsework openings);
- environmental factors;
- depth of structure;
- allowable locations of piers;
- foundation conditions;
- waterway opening requirements;
- safety of underpassing traffic;
- navigational requirements; and
- flood debris considerations.

See Section 11.5 for DOT&PF practices for span ranges of various superstructure types.

11.3.1. Waterway Crossings

Typically, place abutments for bridges crossing streams and rivers at the banks of the river so that the bridge does not affect flow. In addition, abutments can also be placed a sufficient distance back from the edge of the banks (outside the "ordinary high-water line") to keep excavations, backfill, and riprap out of the river, often easing environmental constraints. Many Alaska river systems have construction windows, endangered species, and water quality requirements that greatly restrict construction activities within the ordinary high-water boundaries.

Minimize the use of piers, because they add cost and construction time, and reduce the hydraulic opening. Each pier is assumed to collect debris during a flood, which further reduces the hydraulic opening and increases scour. However, more supports allow for a shallower superstructure depth. Streams and rivers almost always require deep foundations. A bridge with foundations that remain out of the water greatly reduces foundation costs and can in many cases be the least cost alternative. Access into a stream or river (usually through adjacent property), pile drilling and driving equipment logistics, river diversions, settling basin requirements, environmental restrictions, and risk of flooding greatly increase the cost of placing a support or multiple supports in a stream or riverbed.

See Section 11.2.2 for a further discussion on hydraulic considerations for bridge design.

11.3.2. Highway Crossings

Highway bridges over other highways ("overcrossings") shall have their abutments set based on the anticipated future width requirements of the highway beneath the bridge. The number of lanes and shoulder widths are based on 20-year traffic projections; however, the *LRFD Specifications* require a 75-year design life for bridges. Traffic projections to 75 years are highly speculative. Consider some provision for future widening beyond 20 years. For example, spill-through abutments can accommodate the future construction of a retaining wall to increase the width of roadway under the bridge.

11.3.3. Railroad Crossings

Figure 1130-1 of the *Alaska Highway Preconstruction Manual* presents vertical clearance requirements for railroad overheads. Horizontal clearances will vary depending on the obstruction type (i.e., crashworthy pier, non-crashworthy pier, embankment) and the possibility of future track expansion; therefore, written direction from the Alaska Railroad is required. Typically, three-span and single-span bridges are built over railroad facilities. In many cases, highway bridges over railroads must be designed at skews over 30 degrees. Coordinate these bridge designs with the Chief Bridge Engineer. See Chapter 24 for more information.

11.4. General Design Considerations

As discussed in this section, the bridge engineer must evaluate certain general design factors in the selection of the structure type and layout.

11.4.1. Definition of Terms

Substructure vs Foundation

The dividing line between substructure and foundation is not always clear. Traditionally, foundations include those elements of the substructure that are in direct contact with, and transmit loads to, the supporting rock or soil. The *Alaska Bridges and Structures Manual* uses this definition.

Substructure vs Superstructure

A similar difficulty exists in separating substructure and superstructure. This *Manual* will refer to the substructure as any component or element (not including the foundation) supporting the bearings. The superstructure then consists of the bearings and all of the components and elements resting upon them.

11.4.2. Live-Load Deflection Criteria

Reference: LRFD Articles 2.5.2.6.2 and 2.5.2.6.3

The *LRFD Specifications* state that the traditional live-load deflection criteria are optional for bridges both with and without sidewalks because static live-load deflection is not a good measure of dynamic excitation. DOT&PF does not require that the live-load deflection criteria be satisfied for final design. Nonetheless, these criteria provide a good starting point for preliminary design. The live-load deflection criteria of the *LRFD Specifications* are calibrated to yield comparable results for the HL-93 notional live-load model as the provisions of the *Standard Specifications for Highway Bridges* with the HS20-44 live-load model.

11.4.3. Jointless Bridges

Where practical, the preferred choice is multiple simple span decked bulb-tee girders tied together with cast-in-place pier diaphragms and semi-integral abutments forming a jointless bridge. Historically, problems with expansion joints include corrosion caused by deicing chemicals leaking through the joints and accumulation of debris and other foreign material restricting the free joint movement. This often results in joint damage, differential elevation at the joints causing additional impact forces, unexpected bridge movements and settlements that affect the joint, and high initial and maintenance costs.

The bridge engineer can eliminate joints with special consideration to:

- load path,
- gravity and longitudinal loads,
- effects of concrete creep and shrinkage and temperature variations,
- stability of superstructure and substructure during construction and service,
- skew and curvature effects,
- the superstructure-abutment-foundation connection design and details,
- effects of superstructure and substructure stiffness,
- settlement and earth pressure,
- effects of varying soil properties and type of foundation, and
- effects of the approach slab and its connection to the bridge.

Jointless bridges in service have demonstrated the ability to perform under the previous considerations. Therefore, in the absence of an in-depth analysis, it is reasonable to design a jointless bridge under the following parameters:

- 3 inches of total movement or less at the abutment, and
- 30 degree skew or less.

11.4.4. Number of I-Girders

Due to the advantages of redundancy, new girder bridges must have a minimum of four girders per span. In general, the cost of a girder bridge increases with the number of girders in the cross section. Conversely, structure redundancy increases with the number of girders. The basic objective is to identify a girder spacing and corresponding number of girders that optimizes the design of the superstructure by providing sufficient redundancy with minimal cost. In addition, consider the structural implications of maintaining traffic across the bridge during future operations to redeck or widen the bridge.

11.4.5. Interior vs Exterior Girders

Reference: LRFD Article 4.6.2.2.1

For economy of fabrication, design all girders within a span identically to the governing condition, either interior or exterior girder. However, detail the girder deck and shear keys of decked bulb-tee girders according to the girder placement in the cross section, either the interior or exterior girder.

11.4.6. Seismic Requirements

Reference: LRFD Articles 3.10, 4.7.4, 5.11, A10.1-3, and 11.6.5

The ability to predict the bridge displacements developed by earthquake motion is limited by the complexity of predicting the movement of the underlying earth material and the response of the structure. Incorporate the seismic requirements of the *Guide Specifications for LRFD Seismic Bridge Design* with the selection of a superstructure, substructure, or foundation type. The seismic demand and the period of the bridge are directly related. Therefore, the structure-type selection will dictate the earthquake resisting system (ERS), ductility capacity, and detailing requirements as specified in the *Guide Specifications*.

Ideally, bridges should have a regular configuration where plastic hinging is promoted in multiple, readily identifiable, and repairable yielding components. "Regular" bridges can usually be proportioned for gravity loads and then checked and detailed to resist seismic demands.

Although the *Guide Specifications for LRFD Seismic Bridge Design* provisions do not discuss preliminary structure-type selection, certain guidelines should be followed. In general, select the structure type with the following considerations:

1. **Alignment**. Minimize horizontal curvature.
2. **Substructure Skew**. Where practical, use substructures with little or no skew. Skewed supports cause rotational response with increased displacements.
3. **Joints**. Use continuous girders when practical.
4. **Foundations**. Do not use shallow foundations if the foundation material is susceptible to liquefaction.
5. **Substructure Stiffness**. Conform to the requirements of Sections 4.1.2 and 4.1.3 of the *Guide Specifications*.

11.4.7. Foundation Considerations

The following applies, in general, to shallow foundations:

Grade Adjustment

When considering structure-type selection, the ability to adjust the structure through jacking is an important issue. Jacking stiffeners or diaphragms may be required for steel superstructures. For bridges supported on shallow foundations, the subgrade may settle differently from the calculated estimates. It is understood that, where superstructures and substructures are integral with each other, this facilitation for adjustment cannot exist.

Consider the nature of the subgrade prior to the final selection and design of the superstructure, substructure, and foundation to ensure adjustability if needed.

Settlement Limits

Experience demonstrates that bridges can accommodate more settlement than traditionally allowed in design due to creep, relaxation, and redistribution of force effects. LRFD Article 10.6.2.2.1 mandates that settlement criteria be developed consistent with the function and type of structure, anticipated service life, and consequences of unanticipated movements on service performance.

11.4.8. Aesthetics

Reference: LRFD Article 2.5.5

Structures should be aesthetically pleasing. The *LRFD Specifications* emphasize and DOT&PF encourages the objective of improving the appearance of highway bridges. In bridge design, the Department promotes uninterrupted lines, contours that follow the flow of forces, and the avoidance of cluttered appearances.

Any bridge design must integrate three basic elements: efficiency, economy, and appearance. Regardless of size and location, consider the quality of the structure, its aesthetic attributes, and the resulting impact on its surroundings.

The bridge engineer should adhere to the following design guidelines for aesthetic treatments of bridges:

- Use a consistent bridge design
- Use simple substructure and support features
- Consider fill embankments, bridge rails, and approach rails as part of the bridge design
- Select vandalism-resistant finishes

- Create a visual design unity among all existing and new structures along a highway segment
- Integrate landscape and aesthetics at the onset of project planning

11.4.9. Construction

General
The bridge engineer must review and recommend (to the construction Project Engineer) the approval or rejection of all erection or construction plans required by the contract documents.

Access and Time Restrictions
Water-crossing bridges will typically have restrictions associated with their construction. Consider these during structure-type evaluation.

Regulations administered by various state and federal agencies may restrict the time period that the Contractor will be allowed to work within the waterway. Depending on the time limitations, a bridge with fewer piers or faster pier construction may be more advantageous even if more expensive.

Staged Construction
Occasionally, due to the proximity of existing structures or a congested work area, it may be necessary to build a structure in multiple stages. The arrangement and sequencing of each stage of construction is unique to each project, and the bridge engineer must consider the requirements for adequate construction clearances and the requirements of the traveling public. If staged construction is required, include a staging sequence and controlling lane/construction dimensions in the contract documents.

Construction Costs
Initial construction cost is one factor in the selection of the structure type, but not the only factor. Also consider future expenditures during the service life of the bridge. The initial costs depend on a variety of factors including:

- type of structure
- economy of design
- market conditions
- experience of local contractors
- fabrication shop location
- local availability of structural materials and labor

Falsework
Falsework is an expensive construction item. If the bridge is over a waterway, will have a high finished elevation, or both, the cost of the falsework may become prohibitive, and the bridge engineer must consider other structural systems. The following will apply to the use of falsework:

1. **Railroads**. The Alaska Railroad Corporation (ARRC) has its own requirements for falsework over its facilities. Contact ARRC early in project development to determine if falsework may be used and ARRC's minimum clearance requirements. See Chapter 24 for more information.
2. **Environmental**. Some sites may be very sensitive environmentally, and the use of falsework may be prohibited.
3. **Hydraulics**. For falsework over a waterway, the hydraulics engineer will provide the minimum falsework opening dimensions.
4. **Traffic Impacts**. Constructing falsework over traffic poses a number of risks. Installing and removing falsework requires extended lane closures or expensive traffic crossovers. Vehicular impacts to falsework can pose a hazard to the traveling public and construction workers.

11.4.10. Maintenance and Durability

The structure-type selection will, over the life of the structure, have a major impact on maintenance costs. Based on type of material, the following is the approximate order of desirability from a maintenance perspective:

1. prestressed concrete
2. metalized steel

The following maintenance considerations apply:

1. **Deck Joints**. Open, or inadequately sealed, deck joints are the foremost reason for corrosion of structural elements by permitting the leakage of salt-laden water through the deck. To address this, the *LRFD Specifications* promote jointless bridges with integral or semi-integral abutments, continuous decks, and improvements in drainage.

2. **Bridge Inspection**. In addition to the maintenance needs of the structure, consider the bridge inspection logistics including access. Provide 3 feet minimum head room and a 3-foot wide berm in front of the abutments.
3. **Structural Details**. As another maintenance/inspection consideration, as practical, limit the number of articulated structural details (e.g., bearings, expansion joints).

11.4.11. Future Widening

Consider the possibility of future structure widening. For example, structures supported by single columns or cantilevered piers cannot practically be widened; a separate adjacent structure will be required.

Almost every superstructure type can be widened, but not with the same level of ease. Deck-on-girder bridges and systems consisting of prefabricated elements lend themselves to widening.

11.5. Superstructures

This section discusses those factors that must be considered in the selection of the superstructure type in preliminary design.

11.5.1. General Considerations

Throughout the nation, many types of superstructures have been developed for the myriad applications and constraints that prevail at bridge sites. However, DOT&PF, like other state DOTs, has narrowed its selection of superstructure types to a relatively small number based on DOT&PF's experience, geography, terrain, environmental factors, construction logistics, local costs, local fabricators, the experience and skills of the contracting industry, availability of materials, and DOT&PF preference. Preferred superstructure types promote uniformity throughout the state and simplify the bridge design process.

Substructure/Foundation Type Considerations

The selection of the foundation type typically occurs after the superstructure type selection. See Section 11.7. Therefore, the bridge engineer must anticipate the nature of the foundation characteristics in selecting the type of superstructure. Consider the following:

- **Number of Supports**. The expected foundation conditions will partially determine the number of and spacing of the necessary substructure supports. This will have a significant impact on the acceptable span lengths.
- **Scour**. The geologic or historic scour may have a significant impact on the foundation design which may, in turn, have a significant impact on the superstructure-type selection.

11.5.2. Precast, Prestressed Concrete, Decked Bulb-Tee Girder

Description

Precast, prestressed concrete, decked bulb-tee girders are standardized precast, prestressed T-girders with depths in 12-inch increments starting at 3′-6″ deep. The girders have top flanges that act as the deck through the transverse placement of the girder flange-tip to flange-tip. A membrane and asphaltic concrete overlay typically completes the deck surface.

See Chapter 14 for a detailed discussion on DOT&PF design practices for decked bulb-tee girders.

Typical Usage

Due to its excellent adaptability to the constraints in Alaska, the decked bulb-tee girder is the most common type of superstructure used by DOT&PF. During the last ten years, approximately 80% of the new bridges constructed in Alaska have been this type. In the absence of mitigating factors, DOT&PF uses the decked bulb-tee girder for all spans up to 145 feet on the state highway system and for rural applications where adequate lifting capacity is available for girder erection.

The decked bulb-tee girder bridge can only be used on nearly tangent alignment. As a general guide, decked bulb-tee girders can accommodate a 1-foot chord offset using curved flanges. For larger offsets, a wider bulb-tee girder bridge or another superstructure type (e.g., steel or precast concrete girders with a cast-in-place concrete deck) is a better choice.

Advantages/Disadvantages

Advantages of this structure type include the elimination of the need for a cast-in-place, reinforced concrete deck, moderate to low construction cost, low maintenance cost, no falsework, and fast on-site construction. Its disadvantages include limited ability to adapt to complex geometrics, limited span lengths, and relatively heavy member weight. Precast, prestressed concrete girders require careful handling during transportation and erection. Also, decked girders are heavier than girders without a deck.

Typical Girder Spacing

Because decked bulb-tee girders are placed flange-tip to flange-tip to form the roadway surface area, the girder spacing is equal to the top flange width, which is typically 5 feet to 7 feet.

11.5.3. Special Application Superstructure Types

Composite Steel I-Girders

Description. Composite steel I-girders can be either rolled shapes with spans up to approximately 125 feet or plate girders with spans up to approximately 250 feet. Plate girders can have a constant or variable depth. Abrupt depth changes are not considered aesthetically pleasing. Continuous girders can also be deepened (haunched) at the supports and reduced at the center of the span where vertical clearance is tight. These haunched girders usually have a parabolic variation in depth.

Most structural steel is fabricated out of state, which increases the cost of this structure type. Girder field sections can be easily transported in lengths up to approximately 90 feet. Longer girder segment lengths may be feasible on a case-by-case basis up to 150 feet. Use bolted splices to construct single girder lines up to approximately 1000 feet in length. Consider how this structure type will be erected, where the erection crane(s) will be located, and how the girders will be delivered to the site.

This is a deck-on-girder type of structure; therefore, a cast-in-place or precast deck is required, but the deck can be removed if needed in the future without adversely affecting the steel I-girders. This structure type can also be used with large skews and on horizontal curves, but minimize these geometric features in high seismic regions.

See Chapter 15 for a detailed discussion on DOT&PF design practices for structural steel superstructures.

Typical Usage. DOT&PF typically limits the use of structural steel superstructures to sites where a decked bulb-tee girder superstructure will not work for geometric, environmental, cost, or constructability reasons. In addition, steel girders are used where, in rural applications, bulb-tee girders are too heavy to transport and erect.

If a rolled-beam design is proposed for a new bridge, the contract documents should allow the substitution of a welded plate girder with equivalent plate dimensions at the Contractor's discretion.

Consider the transportation of girders when identifying field splice locations.

Advantages/Disadvantages. When compared to other superstructure types, advantages of composite steel I-girders include relatively simple details and formwork, adaptable to complex geometrics, replaceable decks, and long-span capability. The structural characteristics for composite steel I-girders provide relatively low dead load and, therefore, may be more suitable when foundation conditions are poor.

The disadvantages of composite steel I-girders include moderate to high construction costs, high maintenance costs, and attention to detailing practices. Poor detailing will greatly increase the cost of the bridge and can decrease durability through fatigue cracking. Composite steel I-girders have a higher maintenance cost than concrete bridges. Steel girders are relatively flexible without the bracing provided by the diaphragms and concrete deck, and they require careful handling during transportation and erection.

Typical Girder Spacing. Girder spacings for steel I-girders are normally from 6 feet to 9 feet. Deep plate girder sections benefit the most from wide girder spacings. Shallow plate girders and rolled beams do not accommodate wider girder spacings and may require spacings less than 8 feet when at the limit of the depth-to-span ratios. The bridge engineer can control the design of shallow girder sections by deflection requirements.

Composite Steel Tub Girders

Description. Composite steel tub girders are plate girders with two webs with a common bottom flange. The webs are usually inclined to improve aesthetics and reduce the width of the bottom flange. Spans are economical from about 150 feet up to approximately 300 feet. Steel tub girders can have a variable depth, but this significantly increases the cost of the bridge. They can also be used on very tight-radius curves due to their high torsional stiffness. They do not, however, adapt well to skews or variable widths. Consider fabrication, transportation, and erection of this structure type. Steel tub girders are difficult to handle in the shop due to their size and weight. They require significant bracing during fabrication and erection. Stay-in-place steel forms can provide an innovative top-lateral bracing solution and have been employed by the Department in the past. In addition, steel tub girders are susceptible to thermal movements once erected and require temporary external bracing between boxes.

Typical Usage. For sites where the decked bulb-tee girder is not appropriate, composite steel tub girders are favored over steel I-girders because of their better stability during erection. In addition, composite steel tub girders are also considered in urban areas where a steel-I girder could be used but enhanced aesthetics are desired. However, tub girders are typically not practical in remote areas because of the relatively high girder weight.

Advantages/Disadvantages. Advantages of composite steel tub girder bridges include fast on-site construction, adaptability to tight-radius curves, replaceable deck, and longer span capability. Higher torsional resistance makes it desirable on horizontally curved alignments. Closing the girder section using stay-in-place forms makes the torsional resistance available during erection, increasing girder stability during transportation and erection.

Disadvantages include the high construction costs and not being readily adaptable to skewed or variable-width bridges. Composite steel tub girders require complicated fabrication, welding, and erection. This structure type has higher maintenance cost than concrete bridges.

Typical Girder Spacing. Web spacings are normally 5 feet to 10 feet, resulting in girder spacings of 10 feet to 20 feet. Deep sections benefit the most from wider web spacings. Shallow sections do not accommodate wider girder spacings.

Precast, Prestressed Concrete Bulb-Tee Girders

Description. Precast, prestressed concrete bulb-tee girders are similar to the standard decked bulb-tee girders but with a standard top flange width. A separate deck, either cast-in-place or precast concrete, is required to form the roadway. The practical limitation on span length is 150 feet, although other state DOTs have used span lengths of up to 215 feet. This is a deck-on-girder type of structure; the deck can be removed if needed without adversely affecting the girders. It does not adapt well to large skews and cannot be used on tight horizontal curves (e.g., radii less than 500 feet) or bridges with a variable width.

Typical Usage. Precast concrete girders are generally only used for span lengths up to 145 feet where roadway geometry (i.e., horizontal curvature) dictates the use of a CIP deck and a structural steel system has significant disadvantages. Consider the transportation of girders in selecting girder lengths.

Advantages/Disadvantages. Advantages of this structure type include moderate construction cost, low maintenance cost, replaceable deck, and moderately fast on-site construction. Its disadvantages include the need for a cast-in-place deck, limited span lengths, and slightly higher depth-to-span ratios. Precast, prestressed concrete girders require careful handling during transportation and erection.

Typical Girder Spacing. Girder spacings are normally from 5.5 feet to 7 feet. Concrete strength and the number of prestressing strands usually control the girder spacing.

11.5.4. Superstructure Types Used With Approval

The bridge engineer can consider superstructure types other than the decked bulb-tee girder and special application types may be used, including:

- post-tensioned, cast-in-place box girders,
- steel truss,
- steel-tied arch, and
- cable-supported.

The bridge engineer must investigate the experience of other owners, and the acceptability of these superstructure types must be based upon their successful experiences. The Chief Bridge Engineer must approve the selection of these structure types.

11.6. Substructures

11.6.1. Objective

This section discusses the types of substructure systems used by DOT&PF and their general characteristics. Use this guidance to select the substructure type that is suitable at the site to economically satisfy the geometric and structural requirements of the bridge and to safely use the strength of the soil or rock to accommodate the anticipated loads. Chapter 18 discusses the detailed design of substructure elements.

11.6.2. Abutments

Reference: LRFD Article 11.6

General

Abutments can be classified as flexible or rigid. Flexible abutments transmit earth pressures on the abutments through the superstructure eliminating expansion joints at the end of the superstructure. Semi-integral abutments are flexible abutments. Rigid abutments incorporate expansion joints at the end of the bridge to accommodate thermal movements. Seat-type abutments are rigid abutments. Flexible abutments must be able to accommodate the movements through elastic behavior of the bridge and the surrounding soil because the deck and girders are integral with the abutment. Flexible abutments are considered as pin-ended, expansion bearings in the superstructure analysis. Rigid abutments can be fixed or expansion based upon the choice of bearings.

Abutments may be further classified as either open or closed. Spill-through (or open) abutments are used for most bridges and are placed at the top of the slope. Bridge slopes are typically 2H:1V and based on stability requirements and erosion control.

Closed abutments are used when span lengths need to be reduced. Closed abutments are either a seat abutment or a MSE wall used as an abutment. For closed abutments, there are no fill slopes under the bridge but extensive retaining walls must be constructed. These retaining walls run either along the approaches to the bridge or parallel to the abutment. Retaining walls along the approaches are preferred from a visual perspective. Place closed abutment footings below the level of the highway running beneath the bridge resulting in tall exposed abutment faces.

Spill-through abutments result in longer spans compared to closed abutments, but the total cost is often less compared to closed abutments because spill-through abutments typically have less height. In general, spill-through abutments are considered more aesthetic, provide better sight distance, and more naturally accommodate trapezoidal channel geometry than closed abutments.

Basic Types

Use one of the following basic abutment types, in descending order of preference:

1. semi-integral abutments,
2. seat abutments,
3. MSE walls, and
4. integral abutments.

In general, semi-integral abutments are the preferred abutment type for single and multiple span decked bulb-tee girder bridges and short-span steel girder bridges. For decked bulb-tee bridges with abutment thermal movement greater than about 3 inches, seat-type abutments are typically required.

Semi-Integral Abutments

In semi-integral abutments, the superstructure is extended directly into the abutment backwall. There is no joint in the bridge deck, there may or may not be a pinned connection between the backwall and the pile cap, and there are bearings under the girders.

Floating abutments, where there is no connection between the diaphragm and the pile cap, are frequently used. Usually in a single span bridge, one end (typically the downhill one) will be pinned and the other end free. In a multispan bridge, both abutments will usually be free with fixity provided at the pier(s).

Pinned semi-integral abutments require flexible foundation elements to allow superstructure rotation and thermal motion. Typically, a single row of H-piles will provide the required flexibility for a pinned abutment, but drilled shafts, pipe piles, or spread footings will not. Typically, H-piles are oriented in the strong direction (flanges parallel to the long axis of the cap beam) to provide for greater deformation capacity prior to yielding.

The bridge engineer can use expansion bearings to reduce translation in the substructure.

Seat-Type Abutments

Seat-type abutments consist of a cap beam (supported by piles or columns), seat, and backwall. The superstructure is supported by bearings on the abutment seat. The backwall retains the backfill from the seat up so that the backfill is not in contact with the superstructure.

MSE Walls

Chapter 21 presents DOT&PF criteria on Mechanically Stabilized Earth (MSE) walls and discusses the respective responsibilities of the wall manufacturer and the DOT&PF in their design and construction. The use of an MSE wall as an abutment is a special application of this structural feature. DOT&PF has used two basic conceptual types:

1. **True Abutment**. An abutment supported by an MSE wall, in which the wall rests on a spread footing on top of reinforced earth.
2. **False Abutment**. A pile-supported abutment, in which the MSE wall wraps around an otherwise open abutment.

Do not use MSE wall abutments for bridges crossing waterways. Section 21.2 discusses the use of MSE walls in more detail. Section 18.1.5 discusses the use of MSE-wall abutments. Do not use true abutments in multi-span bridges with piers supported on deep foundations due to potential differential settlement concerns.

Integral Abutments

DOT&PF rarely uses integral abutments because of the inherent incompatibility with frozen ground and extreme thermal ranges. Only consider integral abutments where seasonal freeze of the soil is rarely anticipated. The Chief Bridge Engineer must approve their use.

11.6.3. Piers

Reference: LRFD Article 11.7

General

Piers consist of a pier cap supported on columns, pile extensions, or a pier wall. Extending a deep foundation above ground level to the superstructure, forming a pile extension bent, enhances the economy of substructures.

Pier Caps

Pier caps are usually reinforced concrete members that transfer girder loads into columns, pile extensions, or pier walls. In all cases, use a pier cap. These can be integral with the superstructure, drop (non-integral), or outrigger caps. Drop caps are the most common.

Integral caps may be used with either cast-in-place concrete, precast concrete, or steel girders. Integral caps used with steel girders can be either steel cross girders, cast-in-place concrete, or post-tensioned concrete. Only use an integral cap when necessary. Integral steel caps are often non-redundant, expensive and require precise fabrication. Integral concrete caps with steel girders are difficult to construct, usually require temporary falsework, and do not allow inspection of the top tension flanges after the bridge goes into service.

Use outrigger caps where a column support must extend beyond the edge of the superstructure. Do not use outrigger caps unless necessary. They should be simple spans with pin connections at the top of the columns. Pin connections reduce the torsional shear forces in the outrigger cap. Most outrigger caps are integral concrete and post-tensioned to reduce their depth and to control cracking.

General Usage

Columns, pile extensions, and pier walls are substructure components that support the cap. Use either single or multiple columns depending upon the width of cap and skew of the bridge. For pile extension piers, use either 2, 3, or 4-foot diameter pipe piles. Column sizes for other piers are typically not less than 3 feet in diameter.

The following summarizes DOT&PF typical practice for the selection of a pier type for bridges based on the type of crossing:

1. **Water Crossings**. If the bridge is less than 30 feet above the groundline, a pile extension bent is preferred. Otherwise, use a drilled-shaft, single-column pier, or a wall pier if ice forces require greater lateral resistance.
2. **Railroad Crossings**. If the pier is within 25 feet of the track centerline or future track centerline, use a solid pier wall that satisfies AREMA requirements.

3. **Highway Grade Separation**. Use pile extension bents where the bridge is less than 30 feet above the groundline, or use single columns supported on drilled shafts for a taller bridge.

The following briefly discusses design issues for the piers used by DOT&PF.

Pile Extension Bents

Pile extension bents result in minimal environmental impacts.

Hammerheads (Single-Column Piers)

Single-column or hammerhead piers are typically used where pile extension bents are not feasible and drilled shaft foundations are indicated.

Columns will have circular cross sections, unless a circular column cannot be designed for the required loading. In this case, use an oblong cross section.

The effects of skew can be eliminated by rotating the hammerhead relative to the crossing.

Multi-Column and Wall Piers

Multi-column and wall piers are typically used where spread footing foundations are feasible.

11.7. Foundations

11.7.1. Foundation Type Selection (Overview)

The selection of a foundation type involves an evaluation of the load/structural considerations for the bridge, the geotechnical factors pertaining to the native soils and rock at the site, and where the bridge traverses a waterway, the hydraulic characteristics related to the potential scour. As a starting point, the following presents general DOT&PF practices for selecting a foundation type:

- If the depth to bedrock is less than 10 feet, a spread footing may be the best choice.
- If the height of the bridge pier is less than 30 feet, a pile extension bent is preferred.
- If site conditions do not match either of the above, use a drilled shaft.

In addition, the following lists some of the site-specific factors that should be considered:

- driveability (high-impedance piles),
- constructibility,
- load-carrying requirements,
- scour-susceptibility,
- costs, and
- resource agency permits required.

11.7.2. Structural Foundation Engineering Report (SFER)

Section 17.2 discusses the content and format of the SFER, including the selection of a foundation type.

11.7.3. Types/Usage

The following summarizes DOT&PF's typical practices for the selection of the type of foundation. Chapter 17 discusses the detailed design of foundations.

Driven Piles

In general, DOT&PF uses driven piles where competent rock is greater than 10 feet below design grade and a short pier (height less than 30 feet) is required. In most cases, the best foundation/substructure selection at the site is a driven pile (with a pile extension bent as the supporting pier). Lateral foundation demands may require pile rock sockets. If rock sockets are required, consider drilled shaft foundations as a possible alternative.

If underlying soils cannot provide adequate bearing capacity or tolerable settlements for spread footings, use piles to transfer loads to deeper suitable strata through skin friction and/or point bearing. The selected type of pile is determined by the required bearing capacity, length, soil conditions, and economic considerations. DOT&PF primarily uses steel H-piles or steel pipe piles. See Chapter 17 for more information.

Spread Footings

Reference: LRFD Article 10.6

A spread footing is a shallow foundation consisting of a reinforced concrete slab bearing directly on the founding stratum. At sites with competent soil, spread footings provide a cost-effective foundation. The spread footing geometry is determined by structural requirements and the characteristics of supporting components, such as soil or rock. Their primary role is to distribute the loads transmitted by piers or abutments to suitable soil strata or rock at relatively shallow depths.

The use of spread footings requires firm bearing conditions; competent material (i.e., bedrock) must be exposed or near the ground surface (i.e., a maximum of 10 feet below the ground line). Spread footings are sometimes used where dense glacial till is near the surface and dry. They are not typically used at stream crossings where they may be susceptible to scour and at sites prone to liquefaction. Spread footings are often the best choice for retaining walls, sound barriers, etc.

Settlement criteria need to be consistent with the function and type of structure, anticipated service life, and consequences of unanticipated movements on service performance. Do not allow longitudinal angular distortions between adjacent spread footings greater than 0.008 radians in simple spans and 0.004 radians in continuous spans.

Drilled Shafts

Reference: LRFD Article 10.8

Drilled shafts are the most costly foundation alternative. A drilled shaft (also called a caisson) is a long, slender deep foundation element constructed by excavating a hole with auger equipment and placing concrete, with reinforcing steel, in the excavation. Casing and/or drilling slurry may be necessary to keep the excavation stable.

In general, DOT&PF uses a drilled shaft at bridges more than 30 feet in height (i.e., where a pile extension bent is not feasible) and where a spread footing/pile-supported footing is not feasible for constructability or structural reasons. Constructability concerns are where there are limits on in-stream work or tight construction zones, where driven piles are not economically viable due to obstructions to driving, or where limitations on vibration or construction noise exist. Structural concerns are where driven piles are not economically viable due to high loads and excessive slenderness (height-to-diameter ratio is too great).

11.8. Roadway Design Elements

11.8.1. Coordination

In general, the roadway design criteria will determine the proper geometric design of the roadway, and the bridge design will accommodate the roadway design across any structures within the project limits. This will provide full continuity of the roadway section for the entire project. This process requires proper coordination between the bridge engineer and roadway designer to identify and resolve any inconsistencies.

Initially, the roadway designer sets the geometrics, which are based on the *Alaska Highway Preconstruction Manual*. Check the proposed geometric design (e.g., clearances, horizontal curves, superelevation transitions, vertical curves, longitudinal slope, roadway approach, cross slopes, widths) to identify any modifications that may be warranted to better accommodate structural design considerations. Communicate any proposed modifications to the roadway designer, who will make the final decision on their incorporation.

11.8.2. Vertical Clearances

Figure 1130-1 in the *Alaska Highway Preconstruction Manual* provides the basic vertical clearance criteria adopted by DOT&PF. In addition, where structures with a prescribed vertical underclearance are constructed on spread footings, make allowance for any future settlement that would decrease the clearance. For structures founded in the approach fills, the allowance is 3 inches, unless a greater amount of settlement is expected.

DOT&PF policy is to provide an 18-foot vertical clearance for highways beneath railroad bridges for the Port of Anchorage to North Slope corridor to accommodate overheight loads.

11.8.3. Structure Length Calculations

The overall structure length is measured from the earth side face of the abutment to the earth side face of abutment. The following figures present criteria for determining structure length:

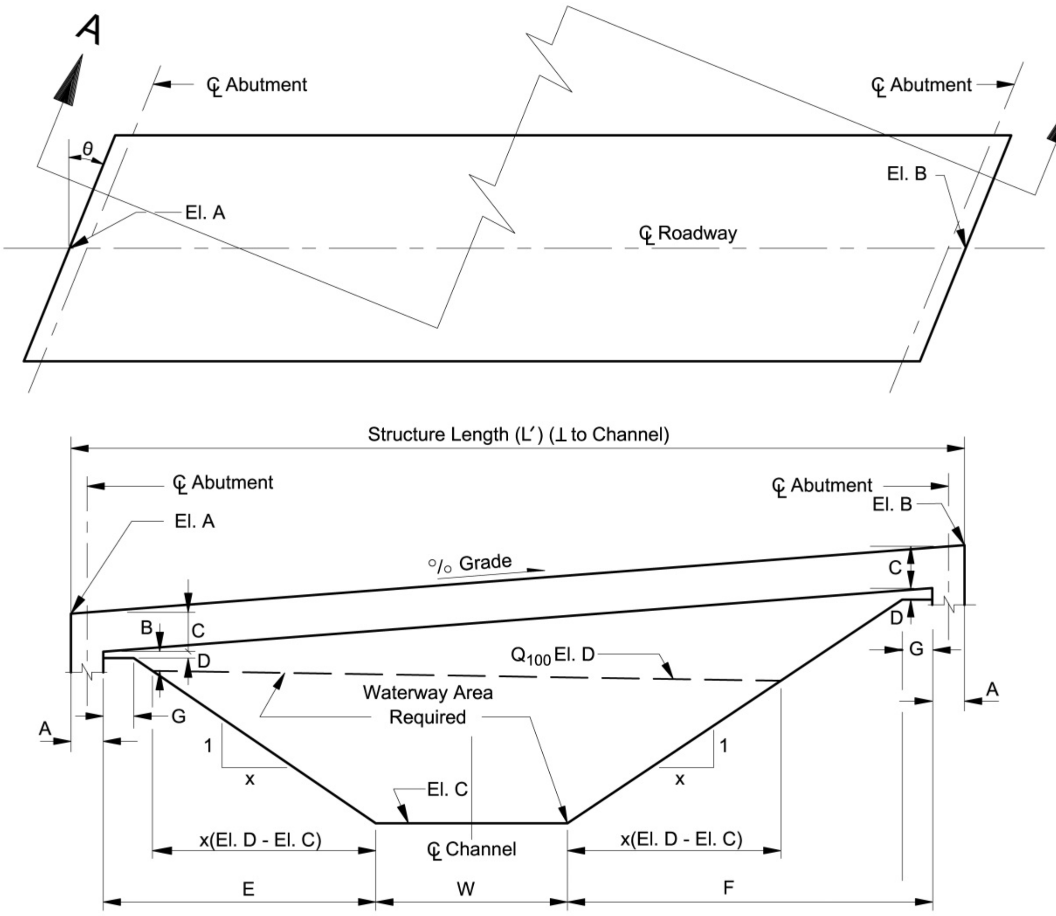
- Figure 11-2 “Structure Length for Stream Crossings”
- Figure 11-3 “Structure Length for Highway Crossings”

See Chapter 24 for highway bridges over railroads.

The major variables that determine the structure length are:

- the use of a spill-through abutment or seat abutment;
- seat width;
- for spill-through abutments, the slope;
- for waterway crossings, the waterway opening dimensions;
- for highway crossings, the width of the underpassing roadway cross section;
- roadway centerline grade; and
- the skew angle of the bridge.

The following figures assume that the bridge is on tangent and on a constant longitudinal gradient. The presence of a horizontal curve and/or a vertical curve will increase the length of the structure.



SECTION A-A
(Perpendicular to Channel)

θ = Angle of skew
A = Abutment width
B = Freeboard
C = Anticipated depth of superstructure
D = Distance from bottom of superstructure to top of abutment slope
E = (x) (El. A – C – D – El. C) + G
F = (x) (El. B – C – D – El. C) + G
G = Berm width
W = Width of channel (perpendicular to channel)
El. A = Elevation of top of deck
El. B = Elevation of top of deck
El. C = Bottom of channel elevation
El. D = Elevation of water surface at Q_{100}

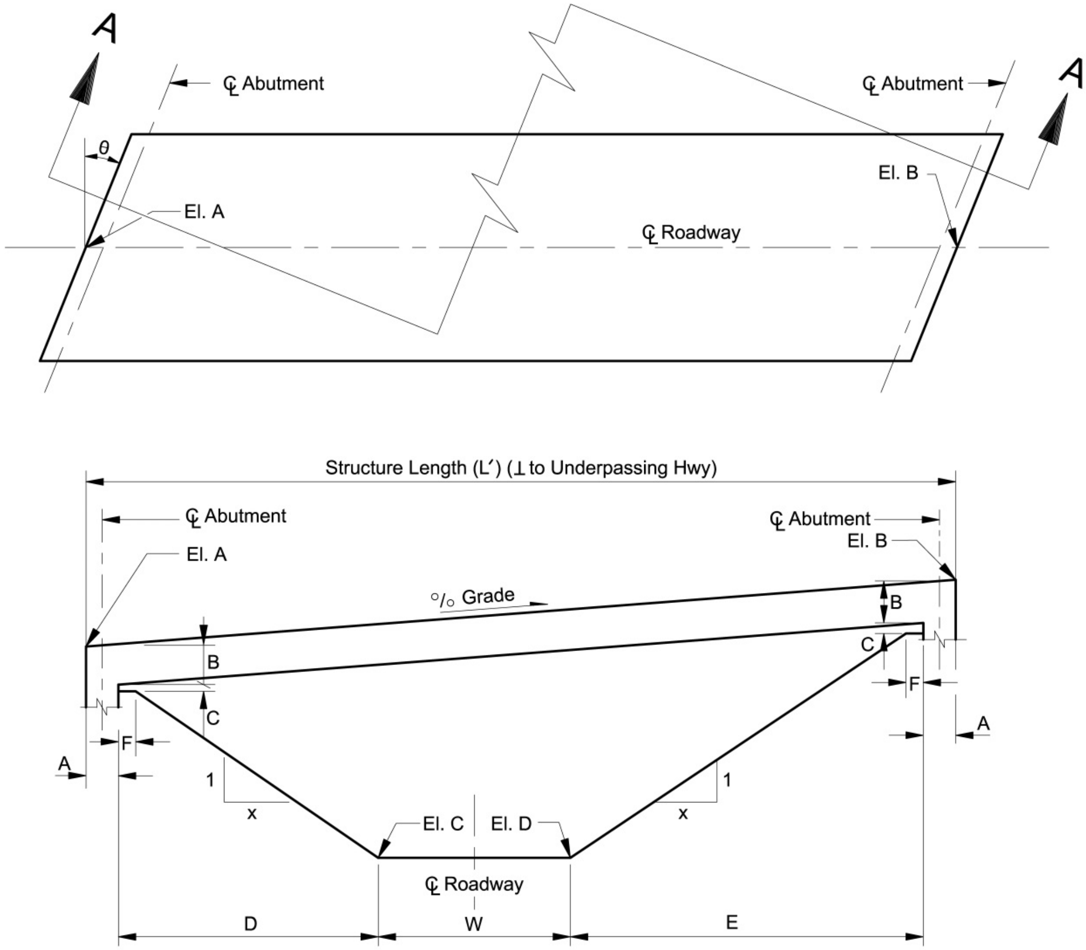
L′ = Structure length perpendicular to channel

L = Structure length along ℄roadway

L′ = A + E + W + F + A

L = L′/cos θ

Figure 11-2
Structure Length for Stream Crossings



SECTION A-A
(Perpendicular to Underpassing Hwy)

θ = Angle of skew
A = Abutment width
B = Anticipated depth of superstructure
C = Distance from bottom of superstructure to top of abutment slope
D = (x) (El. A – B – C – El. C) + F
E = (x) (El. B – B – C – El. C) + F
F = Berm width (3′ typical)
W = Width of underpassing roadway section
El. A = Elevation of top of deck
El. B = Elevation of top of deck
El. C = Elevation of toe of slope
El. D = Elevation of toe of slope

L′ = Structure length perpendicular to underpassing highway

L = Structure length along ℄ roadway

L′ = A + D + W + E + A

L = L′/cos θ

Figure 11-3
Structure Length for Highway Crossings

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