Chapter 14
Bridges

Legend

	Multimodal Application Example
	Context-Sensitive Solutions Application Example
	Performance-Based Practical Design Application Example
	Multimodal (MM)
	Context-Sensitive Solutions (CSS)
	Performance-Based Practical Design (PBPD)
	Web link for additional information
	AASHTO-Specific Information

Chapter 14

14 Bridges

14.1 Introduction

This chapter addresses the basic issues the roadway designer must consider when designing a roadway project that includes major or minor structures. It also describes the required coordination with the other specialty groups in CDOT.

14.2 Scope of Work Development

Refer to the CDOT *Bridge Design Manual*, Policies and Procedures, Section E (CDOT, 2023) for the minimum project scoping requirements for structures.

The Staff Bridge Branch plays an active and early role in the development of the project-specific activities related to highway structures. The Staff Bridge Unit Leader designates an experienced Staff Bridge employee to assist the Project Manager in the project scoping. The designated person is normally the Staff Bridge Unit Leader whose unit performs the structural design. When a consultant does the structural design, the Staff Bridge Unit Leader assigned to the project assists in the scoping and review of the design.

The designated Staff Bridge employee, in conjunction with the Project Manager, identifies the structure-related activities necessary for a project.

The Staff Bridge employee, jointly with the Project Manager, develops a detailed list of the specific information that is needed by the structural design team from others (for example, roadway plan and profile, geotechnical report, architectural treatment guidelines) and establishes a schedule for receipt of this information by the structural design team.

The Staff Bridge employee and the Project Manager establish a schedule for the submittals that are to be made by the structural design team. Refer to Section 14.8.

14.3 Definitions

For additional definitions of structures managed by CDOT and assigned a structure number or structure ID, refer to the CDOT *Bridge Design Manual* Section Policies and Procedures, D (CDOT, 2023).

14.3.1 Major Structures

Major structures are bridges and culverts with a total length greater than 20 feet measured along the centerline of the roadway between the inside face of abutments, inside faces of the outermost walls of culverts, or spring lines of arches. Major structures also include culverts with multiple pipes where the clear distance between the centerlines of the exterior pipes, plus the radius of each of the exterior pipes, is greater than 20 feet. Refer to CDOT *Bridge Design Manual*, Section Policies and Procedures, D (CDOT, 2023).

14.3.2 Minor Structures

Minor structures are bridges, culverts, or a group of culverts that have a length greater than or equal to 4 feet and less than or equal to 20 feet measured along the centerline of the roadway between the inside face of abutments, inside faces of the outermost walls of culverts, or spring lines of arches. Refer to CDOT *Bridge Design Manual*, Section Policies and Procedures, D (CDOT, 2022).

14.3.3 Special Inlet or Outlet

Special inlets or outlets are those with features beyond the customary headwalls, wings, and aprons, as provided in the CDOT Standard Plans - M & S Standards (CDOT, 2019). Examples are trash grates, energy dissipaters, trash walls, integral check dams, steeply sloping inverts, varying culvert size at the culvert end, and non-standard apron details.

14.3.4 Standard CBCs vs. Non-Standard CBCs

Standard concrete box culverts (CBC) are those covered by the current CDOT Standard Plans - M & S Standards without modifications (CDOT, 2019). This does not preclude using the CDOT Standard Plans - M & S Standards as work sheets to provide for custom design and details (CDOT, 2019).

Currently, the CDOT Standard Plans - M & S Standards (CDOT, 2019) are limited to “cell” spans 20 feet and less and opening heights up to 10 feet, typical fill heights between 0 and 20 feet (less for the longer spans and up to 30 feet for triple CBCs), full floor without piles, no change in cross section, and live load of HL-93 Truck, HL-93 Tandem, Colorado Permit Truck, and national rating load (NRL).

Non-standard CBCs are those not described in the CDOT Standard Plans - M & S Standards (CDOT, 2019) in all structural respects. Typically, non-standard CBCs should be used only when standard CBCs cannot reasonably meet the site requirements for loading, span, height, or structural configuration.

14.3.5 Walls

As defined in CDOT *Bridge Design Manual* Section Policies and Procedures, D (CDOT, 2018); and CDOT *Retaining and Noise Wall Inspection and Asset Management Manual* (CDOT, 2016), walls are classified as follows:

- *Retaining Walls.* Walls retaining soil measuring at least 4 feet in height from the finished grade to the top of the wall at any point along the length of the wall.
- *Bridge Walls.* Retaining walls that contribute to the stability of the bridge or bridge approach. Bridge walls exclude wingwalls and culvert headwalls.
- *Noise Walls.* Noise walls of all types including other highway partitions and walls that do not typically retain soil.

14.4 Roadway Elements of Design,

14.4.1 Bridge Roadway Width

The curb-to-curb width of a bridge should carry the full-approach roadway width across the structure. The full-approach roadway width should include the number and width of travel lanes, width of shoulders, and width of guardrail offset prescribed for the particular functional classification of highway defined for the project. Also, it may include any additional roadway width needed for a median, acceleration or deceleration lanes, other auxiliary lanes, bike lanes, and pavement widening on curves. Where possible, avoid tapering medians, acceleration lanes, deceleration lanes, and other auxiliary lanes across a structure or having the transition for pavement widening on the structure.

Where there is combination curb and gutter construction, the gutter pan width shall be part of the shoulder area on the bridge. If that shoulder is being used for a bike lane, the gutter pan should be outside the bike lane area. The flow-line of roadway curb and gutter and the flow-line of the bridge curb should be aligned. This may be accomplished with a 10-foot transition at the approach to the structure. This policy applies to all structures with either concrete or asphalt approach roadways.

For bridges with approach shoulders less than 8 feet, other than those on the mainline of an interstate or other divided highway, the guardrail offset should be 2 feet as specified in M 606-1 of the CDOT Standard Plans – M & S Standards (CDOT, 2019).

14.4.2 Cross Slope

The cross slope on bridge decks shall be, in all cases, consistent with the cross slope of the adjoining roadway. Where possible, avoid having the transition from normal cross slope to full superelevation on a bridge.

14.4.3 Median

The Staff Bridge Branch should be consulted to determine median treatment. Undercrossing roadways may require additional median width to accommodate placement of bridge pier columns.

14.4.4 Horizontal Alignment

The horizontal alignment of bridges should be consistent with the adjoining roadway. Where possible, avoid alignments that place spiral curves on structures. More requirements for bridge horizontal alignment can be found in the CDOT Bridge Design Manual, Section 2 (CDOT, 2022).

14.4.5 Vertical Alignment

The vertical alignment of bridges should be consistent with the adjoining roadway. In determining vertical alignment, possible structure depths should be discussed with the Project Structural Engineer so that a variety of structure types that are not limited by the lack of sufficient vertical clearance can be considered. Where possible, avoid alignments that place the bottoms of sag vertical curves on structures. The recommended minimum grade for drainage is 0.5%. For more information refer to the CDOT *Bridge Design Manual*, Section 2 (CDOT, 2022).

14.4.6 Bridge Skew Angle

As defined in the CDOT *Bridge Design Manual,* Section 4 (CDOT, 2022), bridge skew angles are measured between a line normal to the layout lines (either tangents or chords) or girder lines and the centerlines of bearing of bridge spans or other transverse reference lines. Usually, structures are skewed so that the centerlines of the substructure elements (abutments, piers, culvert walls) are parallel to the feature intersected by the roadway alignment. Where possible, avoid horizontal alignments, such as spirals, that increase the number of different skew angles at the various points of intersection on a bridge. Set the skew angle as close to 0 degrees as possible but less than 50 degrees.

14.4.7 Bridge Sidewalks and Bikeways

The Accommodating Bicycle and Pedestrian Travel: US DOT Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations states: “Transportation agencies are encouraged, when possible, to avoid designing walking and bicycling facilities to the minimum standards. For example, shared-use paths that have been designed to minimum width requirements will need retrofits as more people use them. It is more effective to plan for increased usage than to retrofit an older facility. Planning projects for the long-term should anticipate likely future demand for bicycling and walking facilities and not preclude the provision of future improvements.” (USDOT, 2010)

The clear walkway shall meet Proposed Rule Public Right of Way Accessibility Guidelines (PROWAG) (U.S Access Board, 2011). Additional width (up to 12 feet) may be required in a commercial area or near a school or for a shared pedestrian-bikeway facility. The minimum sidewalk width on a bridge shall be 5 feet.

For high-speed (greater than 45 mph), high-volume (greater than 50,000 annual average daily traffic) roadways or those without an approach curb, an approved traffic barrier shall be placed between the travel way and the sidewalk or bikeway.

Bridge railings need to be raised to provide appropriate protections for the pedestrian and cyclist using the bridge as a crossing. Bridge railing height can vary from 30 to 42 inches tall depending upon the type of barrier being considered. When a pedestrian walkway or shared-use path is incorporated into the bridge structure, the barrier height needs to be increased to a minimum of 42 inches above the shared-use path surface. This would also apply to a bike lane on the bridge requiring the barrier to be a minimum of 42 inches tall from the surface of the bike lane. When assessing barrier types for a bicycle or shared-use path facility, the designer should consider pedal strike, handlebar strike, and fall hazards. Refer to Chapters 12 and 13 of this Guide for additional information on pedestrian and bicycle accommodations and the CDOT *Bridge Design Manual* Section 2 (CDOT, 2022).

14.4.8 Embankment Slopes at Bridge Approaches

Embankment slopes at bridge approaches should be 2:1 or flatter. For an interstate undercrossing and other high-speed under crossings, a 4:1 slope should be placed within the clear zone between the bottom of the outside ditch and the start of the 2:1 slope. Slopes should be designed for adequate drainage (refer to Section 14.6.2). More detailed information is shown in the CDOT *Bridge Design Manual*, Section 2 (CDOT, 2023) and the AASHTO *Roadside Design Guide* (AASHTO, 2011).

14.4.9 Clearance to Structures and Obstructions

Minimum horizontal and vertical roadway clearances to structures and obstructions are shown in Table 3-3 of this Guide.

If the bridge is spanning a waterway or other natural environment, the designer should consider whether the bridge will need clearance to accommodate a future connection to a shared-use path and the characteristics of the predominant shared-use path user, such as pedestrians, bicycles, or people riding horses to inform the clearance height.

Unusual clearance problems at a structure should be discussed with the Staff Bridge Branch early in the design process so that effective solutions are found. More detailed information on bridge clearances is shown in the CDOT *Bridge Design Manual*, Section 2 (CDOT, 2022).

14.5 Roadway Design Submittal to Bridge/Structure Designer

14.5.1 Purpose

Normally, the Project Structural Engineer must rely on other members of the design team for site information, horizontal and vertical alignments, hydraulic requirements, and roadway templates.

Well-scoped projects and adequate preliminary information eliminate the need for supplemental survey requests. With electronic surveys, special care must be taken during data collection to obtain adequate site information.

14.5.2 Project Scoping

Refer to Section 1 of the *CDOT Project Development Manual* (CDOT, [2013] 2022) and the CDOT *Bridge Design Manual* Section Policies and Procedures, E1 (CDOT, 2023).

14.5.3 Survey Requests for Bridges

The Project Structural Engineer should be contacted and requested to provide survey requirements prior to making the request for survey. Refer to the CDOT *Survey Manual* (CDOT, 2021).

14.5.4 Roadway Design Submittal to Project Structural Engineer

The roadway design submittal should provide sufficient information to locate the structure vertically and horizontally, as well as to determine the size of structure required. At a minimum, the following must be provided:

- Typical Sections of Upper and Lower Roadways.
- Roadway Plan and Profile Sheets showing proposed alignments.
- Preliminary Hydraulics Recommendations for any structure over a waterway.
- Bridge Situation Sheet showing topography and contours at 2-foot intervals.
- Locations of all known utilities.
- Any applicable Corridor Design Concepts or special architectural features.
- Preliminary Form 463, Design Data.

Submittals in the electronic format must use the CDOT configuration and include all cross-referenced MicroStation drawings. The files must not contain LISP files, special character sets, fonts, shape files, or other customized information required to access the drawing files.

Drawings that represent field data surveyed or proposed design alignments should be represented within the drawing files at true scale and in the correct project coordinate locations. The Staff Bridge Branch shall be contacted for other requirements and submittal formats.

All alignments must be included in the electronic files. Paper copy listings of all points, curves, and horizontal and vertical alignments with stations and coordinates must be provided. A list of which files contain alignments and surfaces would be helpful.

Refer to the CDOT *Bridge Design Manual*, Section Policies and Procedures, E1 (CDOT, 2022).

14.6 Hydraulics Reports

14.6.1 Stream and River Crossings

Although hydraulics reports are written by the hydraulics designer, they are the result of a coordinated, cooperative, multidisciplinary effort. After a joint site visit by the hydraulics designer and bridge designer, a joint memo must be prepared by the hydraulics designer and sent to the Project Manager stating the concerns, conclusions, or issues discussed at the site review. The hydraulics designer provides the bridge designer the hydraulics information needed to start the design of the structure.

After geotechnical borings are taken and analyzed, but prior to the submittal of the Foundation Report, the bridge, hydraulics, and geotechnical engineers discuss bridge site scour conditions.

The Hydraulics Design Engineer then prepares a Final Hydraulics Report and the Bridge Hydraulic Information Plan Sheets.

For more information, refer to the CDOT *Drainage Design Manual* (CDOT, 2019) and the CDOT *Bridge Design Manual* (CDOT, 2023).

14.6.2 Roadside and Bridge Deck Drainage

The Roadway Design Engineer, Hydraulics Design Engineer, and Project Structural Engineer should coordinate and analyze roadway and deck drainage requirements. Problems have occurred where drainage was not adequately addressed. Problems ranged from loss of material around guardrail posts to total loss of embankment and slope paving.

Consideration of drainage is needed where the water flows around the abutment wingwalls or ends and where water may cross an expansion device. Discharging drainage from the structure directly into waterways usually is not permitted, and the handling of drainage should be coordinated with the Region Planning/Environmental Program Manager.

14.7 Special Requirements

14.7.1 Permits

Consider the following regarding permits:

- Coordinate with the Region Planning/Environmental Manager; and the materials and geotechnical, and project structural engineers to obtain all necessary environmental permits. Refer to the CDOT *Project Development Manual* (CDOT, [2013] 2022).
- Construction access to the streambed.
- Right-of-entry permits.
- Temporary easements.
- Maintenance access.

14.7.2 Environmental

It is possible to locate a structure virtually anywhere. However, impact to the environment may weigh in the structure location decision and determine the type of construction. The extent of allowable construction impact to the site must be known to accommodate those limitations in the structure design.

Where a structure is located, and what the structure is founded on affects the construction time required and the cost of a project. Landfills and sites where settlement is likely to occur are less desirable structure locations. Recreational uses of the feature spanned by the structure (e.g., kayak, pedestrian, equestrian), as well as the ability of the structure to accommodate recreational use, must be thoroughly investigated so that specific elements can be integrated into the structure design.

Anticipation of dewatering activities for deep foundations should be checked for water quality and the impacts of settlement to surrounding buildings and the roadway.

Whenever environmental concerns need to be accommodated by the structure, they must be made known early, prior to the start of the structure design.

14.7.2.1 Historic Requirements

Determining whether the existing structure is historic can be a time-consuming process. This determination can also affect the design of a new structure. Early identification of the structure's historic relevance is critical during the initial scoping of the project so that the design schedule accommodates the coordination required. Refer to Section 3.08 of the CDOT *Project Development Manual* (CDOT, [2013] 2022).

14.7.3 Aesthetics

There is a limit to the number of aesthetic treatments eligible for federal funding that can be incorporated into a new structure. The designer should consult with the Staff Bridge Branch and FHWA for eligibility. Consultation with the Colorado Bridge Enterprise program may also be necessary to determine what aesthetic treatments may be allowed. Refer to Section 5.05 of the CDOT *Project Development Manual* (CDOT, [2013] 2022).

14.7.3.1 Structural Coatings

The appropriate type of coating treatment should be discussed early in the process with Region Maintenance and the Staff Bridge Branch.

14.7.4 Utilities

The location and elevation of all utilities in the vicinity of a structure must be known prior to the start of the final structure design. Frequently, conflicts with utilities can be avoided simply by designing around them. Utilities that must remain in service during construction may require temporary support and additional construction staging. The designer should coordinate with the

Staff Bridge Branch as soon as possible if utilities are to be located on the structure. Refer to the CDOT *Bridge Design Manual* (CDOT, 2022).

14.7.5 Construction

14.7.5.1 Detours and Staging

The most desirable construction detour method is to route the traffic around the structure site. However, replacement of a structure and structure widening usually requires traffic to be shifted during construction to create a safe work zone.

Construction staging allows a structure to be built in stages while maintaining traffic. Careful planning must go into the construction staging since the feature spanned by the structure will pass beneath throughout construction. Adequate spacing between the construction stages is required to accommodate placement of temporary barriers and allow sufficient room to work on the structure.

Detour and staging concepts must be developed early because they are necessary for the development of the Structure Selection Report and associated bridge general layout.

Refer to Chapter 6 of this Guide and Section 8.02 of the *CDOT Project Development Manual* (CDOT, [2013] 2022).

14.8 Foundations and Structures

The Staff Bridge Branch and the Geotechnical Branch work together to determine the feasible foundation type. A foundation investigation request from the Project Structural Engineer must be addressed to the Resident Engineer who is responsible for site staking and access clearance. Drilling shall not commence until the Geotechnical Engineer has been notified that access is cleared.

Refer to Sections 5.06 and 6.03 of the CDOT *Project Development Manual* (CDOT, [2013] 2022).

14.9 Structural Design Submittals

The “structure design team” referred to in this section is either the Staff Bridge Branch Design Unit or the consultant firm performing the structural design for the project.

Project submittals by the structure design team are listed below. Except for the last bullet, these submittals are made to the Resident Engineer who makes the necessary distributions. Time frames in parentheses indicate the minimum time required by the project structural engineer to complete the submittal once all necessary information is received. Refer to the CDOT *Bridge Design Manual*, Section Policies and Procedures, E (CDOT, 2023), for additional information.

If the submittal requires review and comment, the normal time frame allowed for the review is given. Prompt and thorough review of the submittals is necessary to ensure adherence to the project schedule. Changes introduced after the Field Inspection Review can result in a considerable amount of additional design time for the structural design team.

The project structural engineer is responsible for:

- *Structure Selection Report.* This report is required for all structures and retaining walls. The report provides the structure type recommended by the structural design team and includes structure general layouts (including retaining walls) and preliminary cost estimates. After the report has been reviewed, it is revised to include all necessary changes and decisions. This updated report identifies the final structure type approved for the project (if different than recommended) and includes the associated General Layout and preliminary cost estimate. This report includes pertinent hydraulic and foundation report information. (Two weeks)
- *Request for foundation investigation.* The structural design team initiates the foundation investigation by identifying the test holes needed as early in the project as is practical. This request is sent to the Resident Engineer with a copy to either CDOT's Geotechnical Engineer in the Materials and Geotechnical Branch or the consultant geologist, as applicable.
- *General Layouts for the Field Inspection Review.* The General Layout in the final Structural Selection Report may be used for the Field Inspection Review set of plans if it has not been revised following review of the Structure Selection Report.
- *Advance Plans and Specifications.* To reduce or eliminate the need to discuss specific structural design details during the Final Office Review, this optional early review of structural details can be conducted. This review also allows changes that require structural redesign to be made without disrupting the post Final Office Review project schedule. (Three weeks)
- *Complete Plans and Specifications for the Final Office Review* set of plans.
- *Final Plans and Specifications* for the advertisement set of plans.
- *Submittal of the structural records on the project.* This submittal is made to the Bridge Management System unit of the Staff Bridge Branch by the structural design team. This project submittal includes the Structure Selection Report, structural design notes, and design check notes, the bridge rating package, and the correspondence file regarding structures.
- *Structural Field Packages.* Submitted to Resident Engineer for use by the Project Engineer to check quantities and assist with resolving questions about the quantity calculations. This includes a copy of the foundation report. The field package may be requested at any time after advertisement of the project.