CHAPTER 15
BRIDGE

15.0 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.

15.1 SCOPE OF WORK DEVELOPMENT

See subsection 19.1 in the CDOT *Bridge Design Manual* **(1)** for the minimum project requirements for major structures.

The Staff Bridge Branch will play an active and early role in the development of the project-specific activities related to highway structures. The Staff Bridge Engineer will designate an experienced Staff Bridge employee to assist the Project Manager in the project scoping. The designated person will normally be the Staff Bridge unit leader whose unit will perform the structural design. When a consultant will do the structural design, the Staff Bridge unit leader assigned to the project will assist in the scoping.

The designated Staff Bridge employee in conjunction with the Project Manager will identify the structure-related activities necessary for the project.

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

The Staff Bridge employee and the Project Manager will establish a schedule for the submittals that are to be made by the structural design team. See section 15.9 .

15.2 DEFINITIONS

15.2.1 Major Structures

Major structures are bridges and culverts with a total length 20 feet or greater and retaining walls with both a total length of 100 feet or greater and a maximum exposed height at any section of over 5 feet. The length is measured along the centerline of roadway for bridges and culverts, and along the top of wall for retaining walls. Overhead sign structures (sign bridges, cantilevers and butterflies extending over traffic) are also major structures.

15.2.2 Minor Structures

Minor structures are bridges with lengths less than 20 feet and culverts with openings less than 20 feet.

15.2.3 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* **(2)**. 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.

15.2.4 Standard CBCs Vs. Non-Standard CBCs

Standard concrete box culverts (CBCs) are those covered by the current CDOT *Standard Plans - M & S Standards* **(2)** without modifications. This does not preclude using the CDOT *Standard Plans - M & S Standards* **(2)** as work sheets to provide for custom design and details.

Currently, the CDOT *Standard Plans - M & S Standards* **(2)** are limited to "cell" spans 20 feet and less and opening heights up to 10 feet, fill heights between 0 and 20 feet (less for the longer spans), full floor without piles, no change in cross section, and liveload of HS20 or Military Alternate.

Non-standard CBCs are those not described in the CDOT *Standard Plans - M & S Standards* **(2)** 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.

15.2.5 Retaining Walls

Retaining walls are any soil and rock reinforcements or structural systems that allow slopes steeper than that allowed by the natural long-term repose angle of the soil or rock behind the wall.

15.3 ROADWAY ELEMENTS OF DESIGN

15.3.1 Bridge Roadway Width

The curb-to-curb width of a bridge shall carry the full-approach roadway width across the structure. The full-approach roadway width shall 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, 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. 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, other than those on the mainline of an interstate or other divided highway, having approach shoulders less than 8 feet, the guardrail offset shall be 2 feet as specified in the CDOT *Standard Plan M-606-1* **(2)**.

More detailed information on Bridge Typical Sections is shown in Section 2 of the CDOT *Bridge Design Manual* **(1)**.

15.3.2 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.

15.3.3 Median

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

15.3.4 Horizontal Alignment

The horizontal alignment of bridges shall be consistent with the adjoining roadway. Where possible, avoid alignments that place spiral curves on structures.

15.3.5 Vertical Alignment

The vertical alignment of bridges shall 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 percent.

15.3.6 Bridge Skew Angle

Bridge skew angles are measured between 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 90 degrees as possible.

15.3.7 Bridge Sidewalks and Bikeways

The FHWA Design Guidance and Policy Statement **(3)** states: "A bridge that is likely to remain in place for 50 years should be built with sufficient width for safe bicycle and pedestrian use (sidewalks and shoulders) in anticipation that facilities will be available at either end of the bridge even if that is not currently the case. Design bridges with sidewalks and shoulders or bike lanes on both sides of the structure."

The clear walkway shall meet current *ADA Accessibility Guidelines for Buildings and Facilities* (ADAAG) (**4**) standards. Additional width (up to 12 feet) may be required in a commercial area or near a school or for a shared pedestrian-bikeway facility.

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

See Chapters 12 and 14 of this Guide and also Section 2 of the CDOT *Bridge Design Manual* **(1)**.

15.3.8 Embankment Slopes at Bridge Approaches

Embankment slopes at bridge approaches shall be 2:1 or flatter. For an interstate undercrossing and other high-speed undercrossings, a 4:1 slope shall 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 (see section 15.5.2). More detailed information is shown in Section 2 of the CDOT *Bridge Design Manual* **(1)** and also the AASHTO *Roadside Design Guide* **(5)**.

15.3.9 Clearance to Structures and Obstructions

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

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 Section 2 of the CDOT *Bridge Design Manual* **(1)**.

15.4 ROADWAY DESIGN SUBMITTAL TO BRIDGE/STRUCTURE DESIGNER

15.4.1 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.

15.4.2 Project Scoping

See Section 1 of the CDOT *Project Development Manual* **(6)**.

15.4.3 Survey Requests for Bridges

The Project Structural Engineer should be contacted and requested to provide survey requirements prior to making the request for survey. See the CDOT *Survey Manual* **(7)**.

15.4.4 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 shall 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 shall be included in the electronic files. Paper copy listings of all points, curves, and horizontal and vertical alignments with stations and coordinates shall be provided.

See subsection 19.1 of the CDOT *Bridge Design Manual* **(1)**.

15.5 HYDRAULICS REPORTS

15.5.1 Stream and River Crossings

Although hydraulics reports are written by the hydraulics designer, they will be the result of a coordinated, cooperative, multi-disciplinary effort. After a joint site visit by the hydraulics designer and bridge designer, a joint memo will 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 will provide the bridge designer the hydraulics information needed to start the design of the structure.

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

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

For more information, see the CDOT *Drainage Manual* **(8)** and Section 19 of the CDOT *Bridge Design Manual* **(1)**.

15.5.2 Roadside and Bridge Deck Drainage

The Roadway 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. Also 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 bridge directly into waterways usually is not permissible and the handling of drainage should be coordinated with the Region Planning/Environmental Program Manager.

15.6 SPECIAL REQUIREMENTS

15.6.1 Permits

Consider the following:

- Coordinate with the Region Planning/Environmental Manager, the materials and geotechnical, and project structural engineers to obtain all necessary environmental permits. See the CDOT *Project Development Manual* **(6)**.

- Construction access to the streambed.

- Right-of-entry permits.

- Temporary easements.

- Maintenance access.

15.6.2 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 will affect 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 use of the feature spanned by the structure (i.e., kayak, pedestrian, equestrian) as well as the ability of the structure to accommodate recreational use must be thoroughly investigated for integration in the structure design.

Anticipation of dewatering activities for deep foundations should be checked not only for water

quality but also 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.

15.6.2.1 Historic Requirements

The activity of determining whether the structure is historic can be a timely process. See Section 2.06 of the CDOT *Project Development Manual* **(6)**.

15.6.3 Aesthetics

There is a limit to the amount of aesthetic treatments eligible for Federal funding that can be incorporated into the structure. The designer should consult with the Staff Bridge Branch and FHWA for eligibility. See Section 4.05 of the CDOT *Project Development Manual* **(6)**.

15.6.3.1 Structural Coatings

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

15.6.4 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. Coordinate with the Staff Bridge Branch if utilities are to be located on the structure.

15.6.5 CONSTRUCTION

15.6.5.1 Detours and Staging

Construction with traffic detoured around the structure site is the most desirable detour method. However, replacement of a structure and structure widening usually requires traffic to be shifted during construction to create a safe work zone. Staging of construction 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 space between the construction stages is required to allow placement of temporary barriers and allow sufficient room to allow work on the structure. Information about utilities carried by the structure, such as size, location, elevation, and whether they are to remain in service during construction must be known before the start of the structure design.

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

See Chapter 3 of this Guide and Section 7.02 of the CDOT *Project Development Manual* **(6).**

15.7 FOUNDATIONS AND STRUCTURES

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

See Sections 4.06 and 5.02 of the CDOT *Project Development Manual* **(6).**

15.8 STRUCTURAL DESIGN SUBMITTALS

The structure design team referred to below is either the Staff Bridge Branch Design Unit or the consultant firm performing the structural design for the project.

The following project submittals will be made by the structure design team. Except for the last bullet , these submittals will be made to the Resident Engineer who will make 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.

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:

- Initial Structure Selection Report. This report is required for all major bridges and retaining walls. The report shall provide the structure type recommended by the structural design team and shall include preliminary structure general layouts (including retaining walls) and preliminary cost estimates. (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 shall be 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.

- Final Structure Selection Report. After the initial report has been reviewed, it shall be revised to include all necessary changes. This updated report shall identify the final structure type approved for the project and provide the associated General Layout and preliminary cost estimate. This report, if practical, should include hydraulic and foundation report information. (Two weeks)

- 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 is made. 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 shall include a copy of the foundation report. The field package may be requested at any time after advertisement of the project.

REFERENCES

1. CDOT *Bridge Design Manual*, Colorado Department of Transportation, 2002.
2. CDOT. *CDOT Standard Plans - M & S Standards*. Colorado Department of Transportation, 2000.
3. FHWA *Accommodating Bicycle and Pedestrian Travel: A Recommended Approach – A US DOT Policy Statement on Integrating Bicycling and Walking into Transportation Infrastructure,* 2000.
4. *ADA Accessibility Guidelines for Buildings and Facilities* (ADAAG). The Access Board, Washington D.C. [http://www.access-board.gov/indexes/accessindex.htm]
5. AASHTO. *Roadside Design Guide,* American Association of State Highway and Transportation Officials, Washington. D.C.: 2002.
6. CDOT *Project Development Manual,* Colorado Department of Transportation, 2001.
7. CDOT *Survey Manual,* Colorado Department of Transportation, 2003.
8. CDOT *Drainage Manual,* Colorado Department of Transportation, 2004.