11STRUCTURES

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11 STRUCTURES

11.1 GENERAL

This chapter provides design guidelines for structures in public rights-of-way. All designs shall be stamped by a registered PE proficient in structural engineering.

11.1.1 Design Standards

Designs of structures shall conform to these Standards and supplemented by the following documents

A. List of Structural Standards to be Followed

1) AASHTO, LRFD Bridge Design Specifications, latest edition.
2) AASHTO, LRFD Bridge Construction Specifications, latest edition.
3) AASHTO, A policy on Geometric Design of Highways and Streets, latest edition.
4) AASHTO, Roadside Design Guide, latest edition.
5) CDOT LRFD Bridge Design Manual (BDM), latest edition
6) CDOT Bridge Rating Manual, latest edition
7) CDOT, Standard Specifications for Road and Bridge Construction, latest edition.
8) CDOT, M&S Standards, latest edition.
9) AASHTO, LRFD Guide Specifications for the Design of Pedestrian Bridges, latest edition
10) AASHTO, LRFD Specifications for Structural Supports, for Highway Signs, Luminaires, and Traffic Signals, latest edition

11.1.2 Borings and Soils Tests

Appropriate borings and soils tests shall be conducted as outlined in **Chapter 5, Soils Investigations**.

11.1.3 Design Approaches

Recognized design approaches for structures in this chapter are as follows:

A. Load and Resistance Factor Design (LRFD)

LRFD enlists both load and resistance factors, derived from the theory of reliability, statistical knowledge of loads, and structural performance. This design philosophy employs explicit use of load variability. AASHTO's LRFD Bridge Design and Construction Specifications uses the LRFD design philosophy, and must be used for all new design.

B. Load Factor Design (LFD)

LFD adjusts WSD to reflect various loads such as vehicular and wind forces. This design philosophy employs a limited use of load variability. These design methodologies are not typically used for new construction and will be allowed only with approval from the agency for special circumstances.

C. Working Stress Design (WSD)

WSD establishes allowable stresses as a fraction or percentage of a given material's load-carrying capacity. Calculated design stresses must not exceed those allowable stresses. These design methodologies are not typically used for new construction and will be allowed only with approval from the agency for special circumstances.

11.1.4 Deflection Control

Designs of all structures in this chapter must include deflection control.

11.2 BRIDGES

11.2.1 General

Bridges shall be considered major structures if the span length between supports is greater than 20 feet.

Bridges shall be considered minor structures if the span length between supports is between 4 feet and 20 feet.

Design Life. All structures shall have a minimum design life of 75 years.

11.2.2 Bridge Load Rating

The design of all structures shall be rated for structural sufficiency prior to approval of the Local Entity of the public improvement plans. The design shall be in compliance with Federal Bridge Rating Guidelines and CDOT Bridge Rating Manual for new bridges. Refer to **Chapter 23, Street Inspection and Testing Procedures, CDOT Road and Bridge Specifications and LRFD Bridge Construction Specifications (for Major Structures),** for further information regarding inspection and rating.

11.2.3 Structure Selection Report

A bridge selection report is required for all structures (unless waived by local engineer) to determine possible structure alternatives that meet project requirements and conditions.

Requirements of the structure selection report is provided in the **CDOT Bridge Design Manual**, Chapter 2.

11.2.4 Vehicular Bridges

Any structure with the intent to carry vehicular traffic as part of the public transportation network shall be treated as a vehicular bridge. Vehicular bridges shall be designed to carry pedestrians and bicycles as well as vehicles. Simultaneous loading of the sidewalk dead load and vehicle live load is required when barrier separation is not present to cover the likelihood of errant trucks mounting the sidewalks or medians.

A. Design Loads

All vehicular bridges shall be designed utilizing a HL-93 design vehicle and load combinations as per **AASHTO LRFD Bridge Design Specifications**

B. Design Details

See the standards mentioned in **Section 11.1.3**concerning design approaches, for further use of design methods. Maximum deflection on a vehicular bridge shall be per **AASHTO, LRFD Bridge Design Specifications**

C. Clear Width

The clear width for new bridges on all streets with curbed approaches shall meet or exceed the curb-to-curb width of the roadway approaches. For streets with shoulders and no curbs, the clear roadway width should be the same as the approach roadway width.

D. Sidewalks

Requirements for sidewalks on bridges are as follows:

1) General. Sidewalks and bicycle lanes will be provided on both sides of the bridge. Sidewalks and/or bike lanes may be omitted from a bridge when separate bike/pedestrian bridges exist or when approved by the Local Entity Engineer.

2) Width Criteria. Width of the pedestrian/bicycle path on bridge shall be the same width as shown in typical sections for roadway classification in Chapter 7 unless alternate width is approved by the Local Entity Engineer. Bridges within the Fort Collins GMA shall have a minimum width of 8’ sidewalks on both sides.

E. Median Barriers

Median barriers shall not be used in an urban setting with design speeds less than 45 mph.

11.2.5 Pedestrian/Bicycle Bridges (P/B Bridges)

P/B bridges shall be designed with the LRFD method as provided by **AASHTO LRFD Bridge Design Specifications** and **AASHTO, LRFD Guide Specifications for the Design of Pedestrian Bridges**.

Whenever vehicle access is not prevented by permanent physical methods or is greater than 6 feet, pedestrian/bicycle bridges shall be designed to accommodate maintenance traffic.

A. Design Loads

1) Vehicular. The minimum design vehicular loading for a P/B bridge follows the H-truck configuration loading. Specific H-truck loading depends upon clear deck width as follows:

Table 11-1
H-Truck Loading

P/B Bridge Width	H-Truck Loading
6 – 10 feet	H-5 truck configuration (10,000 lb)
> 10 feet	H-10 truck configuration (20,000 lb)
< 6 feet	Not wide enough for any vehicles

2) Pedestrian. Do not design for a combination of pedestrian and vehicular loads. Design live loads shall be per **AASHTO, LRFD Guide Specifications for the Design of Pedestrian Bridges**.

B. Wind

Wind Design Factors. Pedestrian bridges shall be designed for wind loads as specified in **AASHTO, LRFD Guide Specifications for the Design of Pedestrian Bridges**.

C. Design Details

1) Deflection. Maximum deflection on a P/B bridge shall be per **AASHTO, LRFD Guide Specifications for the Design of Pedestrian Bridges**.

2) Vibrations. Refer to **AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges** for requirements for vibration limits of pedestrian bridges.

3) Allowable Fatigue Stress. Fatigue provisions are not required for pedestrian live load stresses where heavy pedestrian loads are infrequent. Fatigue provisions shall be included for wind loads.

4) Minimum Thickness of Metal. Closed structural tubular members shall have a thickness of at least 1/4 inch, at the end of 75 years design accounting for corrosions.

11.3 RAILINGS

11.3.1 General

A. Purpose

Railings offer protection to pedestrians, bicyclists, and motorists. They can be designed to retain and redirect vehicles upon impact or to prevent rollover with high center of gravity vehicles. Railings provide a transition from a roadway or pedestrian/bicycle way to a bridge.

B. Using Rigid Railings

Railing systems can be rigid, or they can allow deflection to reduce penetration. Highway structures normally warrant the use of a rigid railing.

C. Compliance with Standard Drawings

This section provides criteria for roadside/bridge, pedestrian, bicycle, and combination barriers. Railings shall comply with **CDOT and AASHTO Standards**

11.3.2 Traffic Railing

A traffic railing is used for roadway traffic when there is a hazard within the clear zone. It is also used to separate the travel lane from an attached sidewalk in cases where there is no bike lane and the posted speed is greater than or equal to 40 mph. Two types of traffic railing are the bridge railing and the roadside barrier.

A. Bridge Railing

Bridge railings must handle vehicles on the bridge under impact conditions. Vehicles and impact conditions are specified in the design. When selecting the rail bridge rail consideration should be given to a system that reduces maintenance and future repair costs. Where feasible an open rail system is preferred to prevent snow/ice buildup. A NCHRP Report 350 Test Level 3 is required for all railings unless approved by the Local Entity Engineer

1) Types of Railings (Crash-Tested)

   i) CDOT Railing – Type 10, This is a combination concrete and steel railing that provides openings to promote snow and ice melting.

   ii) CDOT Railings. Type 7, This is solid rigid concrete system

2) Using Other Types of Railing.

   The utilization of Figure 11-1 is approved on local and collector streets. This railing is not crash tested approved but must be designed by professional engineer per AASHTO LRFD Bridge Design Specifications

3) Other railing may be proposed for review and approval by the Local Entity.

Structural calculations or crash test results need to be submitted with such proposals. For a designed railing system that is not one of the standard CDOT rails mentioned above, the railing system shall be designed in accordance **AASHTO LRFD Bridge Design Specifications**, Section 13.7.

4) Transitions. Transitions shall be provided when a semi-rigid roadside guard rail meets a rigid bridge railing per AASHTO Roadside Design Guide

i) Gradual Stiffening. The transition shall provide a gradual stiffening of the approach by adjusting the post spacing or rail strength or by transitioning to a different, stiffer barrier.

ii) Alternatives in Congested Areas. In urban areas or where city streets and/or sidewalks prevent installation of approach guardrail transitions, one or more of the following alternatives shall be followed:

(a) Install a crash cushion (i.e. Quadguard II) or a section of approach guardrail parallel to the roadway with a suitable end terminal may be used.

(b) Extend the guardrail or bridge rail in a manner that prevents encroachment of a vehicle onto any roadway system near the bridge. A lower test level end treatment or a tapered end section parallel to the roadway may be an option on low speed local or collector roadways.Restrict speed. See **Chapter 14, Traffic Signals, Signs, and Striping,** for regulatory signs. Local Entity Engineer approval is required for this option.

(c) Provide a recovery area.

5) Placement and Lateral Clearance. The rail system shall be placed 2 feet beyond the useable shoulder when possible. Near bridge approaches, the use of longer guardrail posts or structural guardrail mounted on a moment slab under roadway may be viable options if space is limited.

6) Transitioning From Bridge Railing When Outside of Clearzone. If the edge of the bridge railing is outside of the clearzone per the AASHTO Roadside Design Guide then no roadside guardrail is required. This typically happens on slow speed roadways with wide sidewalks or on trailing ends of the bridge.

B. Roadside Barrier

A roadside barrier railing shields motorists from natural or manmade obstacles located along either side of a traveled way. Barriers are required only when the warrants, contained in the **AASHTO Roadside Design Guide**, are met. A NCHRP Report 350 Test Level 3 is required for all railings unless an alternate railing is approved by the Local Entity Engineer

1) Common Roadside Barriers. Roadside barriers are flexible, semi-rigid, or rigid. Refer to **AASHTO Roadside Design Guide** for the most applicable roadside barrier for a given situation.

2) Transitions. As a roadside barrier transitions from the roadway to a bridge a gradual stiffening will be required per **AASHTO Roadside Design Guide**.

3) Placement and Lateral Clearance. Placement of roadside barriers shall relate to lateral offset, terrain effects, flare rate, and length of need.

    i) Lateral Offset from the Edge-of-Traveled Way. Roadside barriers shall be placed as far from the traveled way as conditions allow. The "shy line offset" is defined as the distance from the edge of the traveled way beyond which a roadside object will not be perceived as an obstacle. A roadside barrier should not be placed beyond the shy line offset listed in the **AASHTO roadside design guide, Table 5.7.** The offset is calculated as a function of design speed, especially for short, isolated installations. For long, continuous runs of railing, this offset distance is not as critical.

    ii) Deflection Distance. A barrier's deflection distance on impact is a critical factor in its placement. If a rail is installed along the face of an exposed pier, abutment, or wall, sufficient clearance shall be provided to allow dynamic lateral deflection. This will enable the rail to cushion and deflect an errant vehicle. See **AASHTO Roadside Design Guide, Table 5.6** for appropriate distance required.

    iii) Terrain Effect. Most roadside barriers are designed and tested on level terrain. **Refer to AASHTO Roadway Design Guide, Section 5.6.2.2** for appropriate placement of barriers adjacent to the roadway with slopes greater than 1:10.

    iv) Length of Need. See **AASHTO Roadside Design Guide** for length of need requirements.

11.3.3 Pedestrian Railing

A pedestrian railing shall be used at all locations where pedestrians are adjacent to a 2:1 or steeper drop-off equal to or greater than 30 inches high.

A. Placement

The railing shall be placed on the outer edge of the sidewalk when pedestrian traffic is separated from vehicular traffic by a traffic railing. Pedestrian railing height shall be a minimum of 42 inches, measured from the walkway surface and in accordance to the **AASHTO LRFD Bridge Design Specifications**, Section 13.7.3.2

B. Construction Materials

Permanent pedestrian railing shall consist of either concrete or metal.

C. Design Loads

Pedestrian Railing live loading will be per **AASHTO LRFD Bridge Design Specifications**, Section 13.8.2.

11.3.4 Bicycle Railing

A bicycle railing shall be used wherever bicycles are allowed adjacent to the edge of a bridge or hazard.

A. Placement

The bicycle railing shall be placed on the outer edge of the bike lane. Bicycle railing height shall be a minimum of 48 inches, measured from the riding surface

B. Construction Materials

A bicycle railing shall be constructed of metal rails only, metal rails above a concrete parapet is authorized.

C. Design Loads

See **AASHTO LRFD Bridge Design Specifications**, Section 13.9.3.

11.3.5 Combination Pedestrian, Vehicle and/or Bicycle Traffic Barrier

A. Conditions for Use

The combination barrier shall be provided whenever a raised curb and an attached sidewalk exist adjacent to a roadway.

B. Placement

The combination barrier shall be installed adjacent to the roadway with either a pedestrian or bicycle railing, as appropriate. If the sidewalk width is 6 feet or greater, the railing height shall be a minimum of 48 inches, measured from the riding surface. The combination barrier shall be placed on the outboard side. See **AASHTO LRFD Bridge Design Specifications**, Section 13.10

11.4 RETAINING WALLS AND ABUTMENTS

11.4.1 General

A. Description

Retaining walls and abutments will be designed per **CDOT Bridge Design Manual** and the **AASHTO LRFD Bridge Design Specifications**, Chapter 10. All retaining walls greater than 30” shall be designed by a State of Colorado Professional Engineer with structural calculations provided to the local entity Engineer upon request. Although the local entity cannot dictate the type of wall used, the project structural and geotechnical engineers should coordinate to select and design an appropriate wall system capable of meeting project requirements.

B. Placement of Walls

1) Avoid Placement in Right-of-way

Retaining walls are discouraged within the public right-of-way. They will be allowed only when necessary to support public improvements and when approved by the Local Entity Engineer.

2) Requirements When Beyond Right-of-way

Retaining walls needed to support private improvements shall not be located in the public right-of-way. However, if the failure of a related retaining wall could threaten any improvements or safety within the right-of-way, the Local Entity shall require it to be designed by a State of Colorado Professional Engineer with structural calculations provided to the local entity Engineer upon request.

3) Relationship to Shoulder

Full or partial height walls shall not be located closer than the outer edge of shoulder. Walls shall be outside of roadway clearzone per the AASHTO Roadside Design Guide. If retaining wall is within clearzone and is considered a roadside obstacle per **Section 5.2.2** in the **AASHTO Roadside Design Guide** then an appropriate protective barrier shall be installed to protect motorist from obstacle.

4) Retaining Wall at Roadway Level

When the top of the retaining wall is at the level of a roadway, the face of the parapet wall or rail shall be at least 4 feet from the edge of the traveled way. If retaining wall is within clearzone and is considered a roadside obstacle per **Section 5.2.2** in the **AASHTO Roadside Design Guide** then an appropriate protective barrier shall be installed to protect motorist from obstacle.

11.5 BURIED STRUCTURES

A buried structure is a feature constructed by embankment or trench methods. Buried structures may be constructed of precast or cast-in-place concrete, aluminum, steel, or thermoplastic materials. Refer to Section 11 of the **CDOT Bridge Design Manual** and the **AASHTO LRFD Bridge Design Specifications.** If the buried structures are being considered due to hydraulic reasons then the Local Entity stormwater requirements shall also be utilized.