SECTION 12
BURIED STRUCTURES AND TUNNEL LINERS

12.1 GENERAL REQUIREMENTS

This section covers the design of buried structures, including, but not limited to, precast and cast-in-place concrete box culverts, wildlife crossings, tunnels, and pipes.

12.2 CODE REQUIREMENTS

Design shall be in accordance with AASHTO, unless modified herein.

Chapter 9 of the Drainage Design Manual shall be referenced for buried structures that convey water.

12.3 GEOTECHNICAL REQUIREMENTS

All major structures, as defined in Part D of the Policies & Procedures section of this BDM, require a geotechnical analysis. Minor structures may require a geotechnical investigation when issues such as thrust blocks, large settlement, and deep foundations affect the design.

12.4 CONCRETE BOX CULVERTS

12.4.1 Design Criteria

CIP and precast concrete box culverts (CBCs) and wingwalls shall be designed according to the applicable M-Standard drawings and design criteria. Designs not meeting the standard sizes, loadings, or conditions provided in the M-Standard drawings require a site-specific design. Site-specific design is generally required for non-standard box culvert spans or heights, CBCs with top and/or bottom corner chamfers, live load surcharge greater than 2 ft., fill heights or wearing surface thickness greater than those listed in the M-Standards, wingwalls subject to live load surcharge, and headwalls subject to live load impact, including transfer of live load impact into the top slab. A site-specific design may provide significant cost savings, especially in the case of long CBCs due to the conservative nature of the assumptions used to develop the design tables.

Site-specific designs shall follow AASHTO standards and design criteria listed in this section. Thrust (axial compression) shall be assumed to be zero for design of CIP and precast culvert top and bottom slabs. Wingwalls shall be monolithic and rigidly connected to concrete headwalls to reduce the possibility of differential movement. The design of M standard M-601-20 is based on this assumption of 2 way action. In the event that a non-rigid connection is allowed by the unit leader, an independent wingwall design and check is required.

The limits of a CBC should be kept within CDOT right-of-way (ROW). If the end of a culvert extends beyond the ROW, the Engineer shall provide inspection access from within the ROW.

12.4.2 Loading

When designing non-standard CBCs, live load is applied as follows:

- For design of culvert walls and bottom slabs, only the design lane load is applied.
- For design of culvert top slabs, only axle loads of the design truck or design tandem are applied.

Apply live loads to both earth pressure cases shown in the M-Standard and as described in AASHTO 3.11.7 and AASHTO C3.11.7. Note that, due to the 50 percent reduction in earth pressure, the minimum load factor need not be applied to the 30 lb/ft^3 horizontal earth pressure load case. Live load distribution for various earth fills shall be per AASHTO 12.11.2.1. For CBC designs using either M-Standard or site-specific method, the controlling fill heights shall be shown on the plans. Designer shall consider live load on travel lanes and shoulders and any future roadway expansion.

It is preferred that bottom slabs for non-standard designs be modeled as rigid, not using soil springs, unless significant benefits can be demonstrated.

Thrust (axial compression) shall be assumed to be zero for design of CIP and precast culvert top and bottom slabs. Applying thrust forces is inadvisable when designing non-standard CBCs unless significant benefits can be demonstrated. This criterion is consistent with CBC M-Standard and AASHTO BrR rating software design methodology, and is conservative due to unpredictable on-site foundation conditions and preparations. The Engineer may consider the benefits of thrust forces in non-standard designs but shall discuss its use in the Structure Selection Report and obtain approval from CDOT Unit Leader in coordination with the Staff Bridge Manager of Policy and Standards.

12.4.3 Replacement

Existing culverts under consideration for replacement, extension, or other modifications shall be assessed as part of the Structure Selection Report. A culvert that shows no visible distress but yields an operating rating factor less than 1.0 when rated in accordance with the Bridge Rating Manual is not necessarily a candidate for replacement; refer to Section 33 – Rehabilitation of Structures of this BDM for additional information. Considerations for keeping an existing culvert include the age and condition of the existing culvert compared with the constructability and economy of a proposed replacement.

12.4.4 Stream Crossing

When designing non-standard CBCs, the Engineer shall consider both the presence and absence of water to determine controlling force effects acting on a CBC. Design water levels shall be in accordance with the maximum headwater to depth ratios provided in Table 9.3 in the Drainage Design Manual, unless otherwise directed by a Hydraulic Engineer. While required for design, water loads may be excluded when performing load ratings.

If requested or recommended by CDOT Environmental, water slowing devices may be required to assist upstream fish passage through culverts. Concrete aprons shall be provided as recommended by a Hydraulic Engineer.

12.4.5 Pedestrian Crossing

Pedestrian underpasses shall be designed to remain dry by providing waterproofing etc. and provide a clear line of sight through the underpass. Precast and steel arch structures shall use seals between joints to prevent water leaks. The Engineer shall reference the CDOT Lighting Design Guide for lighting requirements. CDOT shall approve lighting plans designed by a qualified lighting designer. The minimum opening provided for pedestrian crossings and equestrian paths shall be 10 ft. high by 10 ft. wide.

12.5 WILDLIFE CROSSING

Open-span bridges and overpasses are CDOT's preferred structure types for wildlife crossings, followed by arch structures and, lastly, CBCs. For guidance, refer to Wildlife Crossing Structure Handbook - Design and Evaluation in North America (FHWA-CFL/TD-11-003, March 2011) and Safe Passage: Developing Effective Highway Crossings for Carnivores and Other Wildlife by Bill Ruediger (USDA Forest Service, 2007).

The Engineer shall coordinate with CDOT Environmental for guidance on sizing arch structures and CBC crossings. Underpasses designed for deer and elk should be a minimum of 13 ft. high by 23 ft. wide (see Figure 12-1), but preferred dimensions may be greater than those minimums. Coordinate with Environmental group for project specific requirements. If wildlife underpass openings do not meet the minimum dimensions shown in Figure 12-1, a variance is required unless approved by the Environmental group and coordination is documented. All crossings shall provide a line of sight through the structure, and the structure invert elevation shall be below existing grade to maintain the natural path.

The design and layout of wildlife crossings shall include 8 ft. high game fencing and escape ramps at a 3H:1V slope. Game fencing shall be installed between the structure and roadway, rather than terminated at the wingwalls. Note that nonstructural items, such as fencing, are typically the responsibility of the Roadway design team and are included in Roadway bid items.

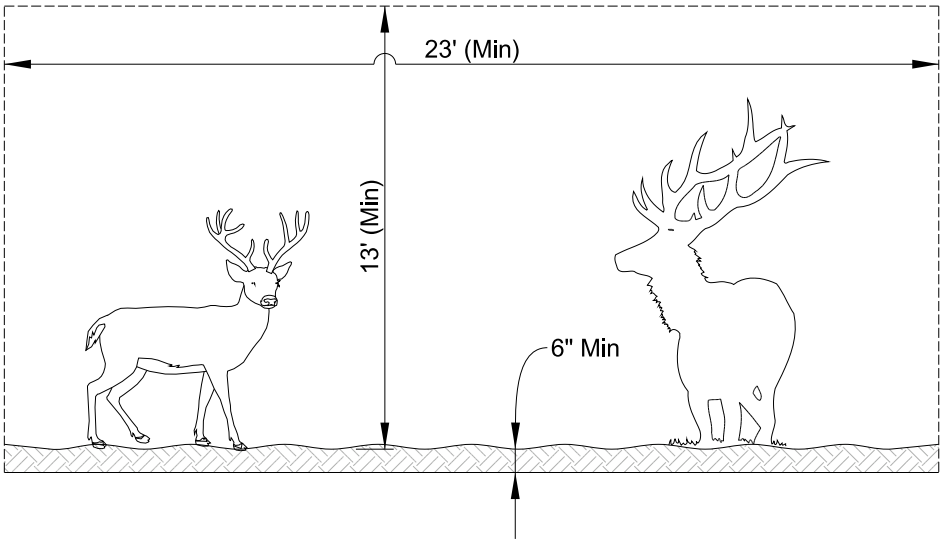

Figure 12-1: Minimum Deer and Elk Underpass Design Dimensions

12.6 TUNNELS

For tunnel design criteria, refer to AASHTO, Technical Manual for Design and Construction of Roadway Tunnels – Civil Elements (FHWA-NHI-10-034), NFPA 502: Standard for Road Tunnels, Bridges and Other Limited Access Highway and AASHTO LRFD Road Tunnel Design and Construction (LRFDTUN).

12.7 PIPES

For design of metal pipe, reinforced concrete pipe, corrugated polyethylene pipe, PVC pipe, metal pipe arches, pipe headwalls and outlet paving, and concrete and metal end sections, refer to the M-Standards.