CHAPTER 11 – STRUCTURES

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CHAPTER 11 – STRUCTURES

11.1 GENERAL

This chapter provides design guidelines for structures in public rights-of-way for new streets. 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, Standard Specifications for Highway Bridges, latest edition.
2. AASHTO, LRFD Bridge Design Specifications, latest edition.
3. AASHTO, LRFD Bridge Construction Specifications, latest edition.
4. AASHTO, A policy on Geometric Design of Highways and Streets, 1990 edition.
5. AASHTO, Roadside Design Guide, latest edition.
6. CDOT, Bridge Manual, Volumes I and II, latest editions.
7. CDOT, Standard Specifications for Road and Bridge Construction, latest edition.
8. CDOT, M&S Standards, 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. 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.

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.

C. 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.

D. AASHTO Approaches

Either of the following **AASHTO** standards may be used to design structures in this chapter unless otherwise specified:

1. AASHTO's Standard Specifications for Highway Bridges uses the WSD and LFD design philosophies.
2. AASHTO's LRFD Bridge Design and Construction Specifications uses the LRFD design philosophy.

11.1.4 Deflection Control

Designs of all three-sided concrete structures in this chapter must include deflection control.

11.2 BRIDGES

11.2.1 General

Bridges shall be considered structures with the span between supports greater than 20 feet.

Design Life. All bridges shall have a minimum design life of 50 years.

11.2.2 Sufficiency Rating

The design of all major structures (span 20 feet) 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 for new bridges. Refer to **Chapter 23, Street Inspection and Testing Procedures,** for further information regarding inspection and rating.

11.2.3 Definition and Types of Bridges

Bridges can be designed to carry various load combinations. This section covers both vehicular and pedestrian/bicycle bridges.

A. Basic Construction Parameters

Bridges shall be constructed of reinforced concrete or, where conditions prevent the use of reinforced concrete, steel. Bridge construction of timber is prohibited unless specifically allowed by the Local Entity Engineer.

B. Span Construction Types

Typical span types and approximate span limitations are shown in Table 11-1.

Table 11-1
Bridge Span Types

Span Type	Approximate Limitations
Reinforced Concrete Slab	< 40 feet
Prestressed Concrete Slab	< 50 feet
Prestressed Concrete Double Tee Girders	< 120 feet
Prestressed Concrete Box Girders	< 140 feet
Prestressed Concrete B-T Girders (Bulb Tee)	< 160 feet
Rolled Beams	< 100 feet; with cover plate up to 120 feet
Plate Girders	< 70 feet
Trusses	**> 140 feet**

11.2.4 Vehicular Bridges

Vehicular bridges shall be designed to carry pedestrians and bicycles as well as vehicles. Any bridges with a clear deck width greater than 20 feet shall be treated as a vehicular bridge.

A. Illumination

Refer to **Chapter 15, Street Lighting,** for bridge illumination requirements.

B. Design Loads

1. Recreational Trails. The minimum design vehicular loading for new bridges used for recreational trails shall accommodate maintenance traffic. The minimum design loading shall be H-15.
2. Vehicular Bridges. All vehicular bridges shall be designed for vehicular loadings of HS-25 or higher.
3. Pedestrian Load. A pedestrian load of 85 psf shall be applied to all sidewalks wider than 2 feet, in combination with vehicular design live load. Sidewalks in this case include wide curbs or other structures that may be used by pedestrians.

C. Design Details

See the standards mentioned in **Section 11.1.3** , concerning design Approaches, for further use of design methods.

1. Deflection. Maximum deflection on a vehicular bridge shall be as follows:

   $D_{max} = S/1000$

   where D = Deflection, feet

   S = Span, feet

2. Minimum Thickness of Metal. Closed structural tubular members shall have a thickness of at least 5/16 inch.

D. 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.

E. Sidewalks

Requirements for sidewalks on bridges are as follows:

1. General. Sidewalks conforming to the street cross sections shall be provided on both sides of a bridge.
2. Width of Parkways. Parkways are not required on the bridge structure in Loveland (GMA and city limits).
3. Extending Approaches. Sidewalks on the approaches shall extend across all bridges.
4. Width Criteria. Refer to sidewalk and bike path width criteria in **Chapter 16, Pedestrian Facilities,** and **Chapter 17, Bicycle Facilities**.
5. Exceptions. Sidewalks and/or bike lanes may be omitted from a bridge when separate bike/pedestrian bridges exist and when approved by the Engineer.

F. 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 are designed to carry primarily pedestrian and/or bicycle traffic as well as the occasional maintenance or service vehicle. This type of bridge will not carry a vehicular roadway.

A. Design Approach

P/B bridges shall be designed with the LFD method as provided by **AASHTO Standard Specifications for Highway Bridges**.

B. 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 11-2
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 as follows:

   a. Main Member. The design pedestrian live load for the Main Member shall be 85 psf, with the following exception: if the deck influence area, A1, is greater than 400 square feet, a reduction may be made per the following equation:

      Pedestrian live load = 85(0.25 + (15/square root of A1)) psf.

      At no time shall the pedestrian live load be less than 65 psf.

   b. Secondary Member. The design live load for the Secondary Member shall be 85 psf.

   c. Deck Loading for Horses or Snowmobiles. Use a concentrated load of P = 1000 lb when horse or snowmobile traffic is present.

C. Wind

1. Wind Design Factors. Wind load is a horizontal load. There is no required combination of wind on live loads (pedestrian or vehicular). For wind overturning force see Section 3.15.3 of **AASHTO Standard Specifications for Highway Bridges**.

2. Specific Load Criteria. The design wind load applied to the vertical area of P/B bridge members shall be as follows:

Table 11-3
Design Wind Load

Member Type	Design Wind Load
Truss and Arches	75 psf
Girders and Beams	50 psf
Open Truss	35 psf

D. Design Details

1. Deflection. Maximum deflection on a P/B bridge shall be as follows:

   $D_{max} = S/1000$

   where D = Deflection, feet

   S = Span, feet

2. Vibrations. Design frequencies shall be as follows:

a. P/B Bridge Without Live Load. When the P/B bridge has no vehicular or pedestrian traffic, the frequency shall be greater than 3 Hz to avoid the first harmonic.

b. P/B Bridge With Live Load. When the P/B bridge has a live load, (e.g., running and jumping), the frequency shall be greater than 5 Hz to avoid the second harmonic.

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.

5. Half Through Truss Spans. Half through truss spans shall be designed per **AASHTO Guide Specifications, For Design of Pedestrian Bridges**, **1997**.

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 **Figure 11-8**.

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. The railing systems listed are used on bridge structures and appear in ascending order of strength or rigidity.

1. Fort Collins (GMA and city limits). All bridge railings for Fort Collins (GMA and city limits) shall conform to **Figure 11-8.**

2. Loveland (GMA and city limits). Bridge railing options for Loveland (GMA and city limits) are given in the referenced construction drawings below.

3. Types of Railings (Crash-Tested).

   a. Oklahoma Modified TR-1 Bridge Railing. This rigid concrete post and beam system reduces snow accumulation to the bridge deck. See **Construction Drawing 1102L**.

   b. BR1 Type C Aluminum Bridge Railing. This metal railing/concrete parapet system has significant strength. It can redirect cars and vans but is not adequate to prevent rollover with high center of gravity vehicles. See **Construction Drawing 1107**.

   c. Safety-Shaped Concrete Bridge Railing. This common bridge railing can redirect heavy trucks and buses. See **Construction Drawing 1103L**.

   d. Nevada Concrete Safety Shape (With Steel Rail). This railing is a raised height system that can contain and redirect a 18,000 kg bus. See **Construction Drawing 1104L**.

   e. Texas Type HT (Heavy Truck). This railing can contain and redirect heavy vehicles. See **Construction Drawing 1105L**.

   f. Texas Type TT (Tank Truck). This extremely strong barrier railing can contain and redirect heavy vehicles. It is very heavily reinforced and rarely used. See **Construction Drawing 1106L**.

4. Using Other Types of Railing. 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.

5. Transitions. Transitions shall be provided when a semi-rigid roadside guard rail meets a rigid bridge railing.

   a. 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.

   b. Flexible Bridge Railings. Transitions may not be necessary when bridge railings have some flexibility. Any design without a transition shall satisfy **AASHTO** criteria referenced in **Section 11.1.1** .

   c. 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:

1) Extend the guard rail or bridge rail in a manner that prevents encroachment of a vehicle onto any roadway system below the bridge. A tapered end section parallel to the roadway may be an option.

2) Provide a barrier curb.

3) Restrict speed. See **Chapter 14, Traffic Signals, Signs, and Striping,** for regulatory signs. Engineer approval is required for this option.

4) Provide a recovery area.

6. Placement and Lateral Clearance. The rail system shall be placed 2 feet beyond the useable shoulder.

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.

1. Common Roadside Barriers. Roadside barriers are flexible, semi-rigid, or rigid. The following are some of the most widely used roadside barriers listed in order of increasing capabilities to contain and redirect large vehicles:

Table 11-4
Roadside Barriers

Category	Type of Barrier	Reference Drawing
Semi-Rigid Systems	Blocked-Out W-Beam (Strong Post)	Refer to M & S Standards
	Blocked-Out Thrie Beam (Strong Post)	**Refer to M & S Standards**
	Modified Thrie- Beam	**Refer to M & S Standards**
Rigid Systems	Concrete Safety Shape	**Refer to M & S Standards**
	Stone Masonry Wall	**Refer to M & S Standards**

2. Transitions. Refer to **Section 11.3.2 A.5**. In the case of roadside barriers, the gradual stiffening will decrease from bridge or structure to roadway.

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

   a. 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 given in **Table 11-5**. 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.

Table 11-5
Suggested Shy Line Offset (L_s) Values

Design Speed (Km/H)	Shy Line Offset L_s (m)
80	12
75	10.5
70	9.2
65	8
55	7.2
50	6.5
45	5.5
40	4.6
30	3.6

b. 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 **Figure 11-1** for this barrier-to-obstruction distance.

c. Terrain Effect. Most roadside barriers are designed and tested on level terrain. Caution must be taken when slopes are as steep as 1:6. **Figure 11-2** shows recommended barrier location on a 1:6 slope.

d. 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.

B. Construction Materials

A pedestrian railing shall be constructed of one of the following materials:

1. Metal fabric.
2. Chain link (vinyl clad only).
3. Metal rails only or metal rails placed above a concrete parapet.

C. Design Loads

See **Figure 11-3** for loading diagram.

1. Metal Rail Design. The design live loading shall be w = 0.050 KLF, both transversely and vertically, acting simultaneously on each longitudinal element. A concentrated load of 0.20 KIPS, acting on the top rail, and simultaneous with the design live loading can be considered at any point and in any direction.
2. Chain Link/Metal Fabric Design. The design live load shall be 0.015 KSF acting normal to the entire surface.

11.3.4 Bicycle Railing

A bicycle railing shall be used wherever bicycle lanes are adjacent to the edge of a bridge or hazard. The railing shall be warranted when the street has designated bike lanes.

A. Placement

The bicycle railing shall be placed on the outer edge of the bike lane. Bicycle railing height shall be a minimum of 54 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, chain link, or metal fabric.

C. Design Loads

See **Figure 11-4** for loading diagram. Design loads are the same as for pedestrian railing in **Section 11.3.3 C**.

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 54 inches, measured from the riding surface. The combination barrier shall be placed on the outboard side. See **Figure 11-5**.

11.4 Retaining Walls and Abutments

11.4.1 General

A. Description

Retaining wall and abutments retain earth with lateral support or at the end of a bridge span, respectively. The design of these structures depends upon: type, function, and anticipated service life of retaining wall, earth pressure exerted on the wall by the retained backfill, geometry, strength and derformability of the ground, groundwater, and welling pressure in clay backfills.

Four types of retaining wall systems are discussed in this section: conventional retaining walls and abutments, anchored walls, mechanically stabilized earth walls, and prefabricated modular walls.

B. Backfill Materials

The backfill materials used shall be granular and free-draining.

C. Drainage

Drainage shall be provided to reduce hydrostatic pressure behind the wall.

D. Design Life

All retaining walls shall have a minimum design life of 50 years.

11.4.2 Conventional Retaining Walls and Abutments

Conventional retaining walls and abutments are proportioned to provide stability against bearing capacity failure, overturning, and sliding.

A. 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 Engineer.

B. 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 to the Local Entity's standards.

C. Loading

Design of conventional retaining walls and abutments shall satisfy the following loading factors:

1. Lateral earth and water pressures, including any live and dead load surcharges.
2. The weight of the wall.
3. Temperature and shrinkage effects.
4. Seismic loads.

11.4.3 Anchored Walls

Anchored walls provide additional lateral resistance with the use of anchors. Their design is based on the suitability of the subsurface soil and rock conditions.

A. Loading

Design of anchored walls shall satisfy items 1, 2, and 4, in **Section 11.4.2 C** above.

11.4.4 Mechanically Stabilized Earth Walls (MSEW)

Mechanically Stabilized Earth Walls (MSEW) are flexible composites of granular soil and tensile inclusions that behave as earth embankments with vertical or nearly vertical faces. MSEW are proportioned to provide stability against overturning and sliding. Bearing pressure generally governs design.

A. Loading

Design of MSEWs shall satisfy items 1, 2, and 4, in **Section 11.4.2 C** above.

B. Application for MSEW

An MSEW should be used where substantial total and differential settlement is expected. This type of wall may also be used where conventional gravity, cantilever, or counterforted concrete retaining walls are considered.

C. Unacceptable Uses of MSEW

An MSEW shall not be used in any of the following conditions:

1. Where utilities other than highway drainage are to be constructed within the reinforced zone.
2. Where floodplain erosion or scour may undermine the reinforced fill zone or any supporting footing.
3. Where surface or groundwater contaminated by acid mine drainage or other industrial pollutants is present.

11.4.5 Prefabricated Modular Walls

Prefabricated modular walls employ soil-filled interlocking modules to resist earth pressures. Stability of modular walls depends upon the weight and strength of the fill soil. Each module level shall be investigated for sliding and overturning.

A. Loading

1. Design of prefabricated modular walls shall satisfy items 1, 2, and 4, in **Section 11.4.2 C** above.
2. Earth pressure shall be computed on a plane surface where modules form an irregular, stepped surface.

3. Ka, used to compute lateral thrust, shall be computed based on the friction angle of the backfill behind the modules.

B. Application for Prefabricated Modular Wall

A prefabricated modular wall may be used where conventional gravity, cantilever, or counterforted concrete retaining walls are considered.

C. Unacceptable Uses of Prefabricated Modular Wall

A prefabricated modular wall shall not be used in any of the following conditions:

1. On curves with radius less than 800 feet, unless the chord can be substituted with a series of chords.
2. Where groundwater or surface runoff is contaminated with acid.

11.4.6 Placement of Walls

A. Relationship to Shoulder

Full or partial height walls shall not be located closer than the outer edge of shoulder.

B. 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.

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. This section covers typical buried structures in the **AASHTO** bridge standards manuals referenced in **Section 11.1.1** .

11.5.1 Design Life.

The design life for buried structures shall be a minimum of 100 years.

11.5.2 Design Loads

A. Non-Vehicular Loads

1. Load Factors. Buried structures shall be designed for force effects resulting from horizontal and vertical earth pressure, pavement load, live load and vehicular dynamic load.
2. Other Load Factors. When relevant for site or construction conditions, earth and live load surcharges and downdrag loads shall also be evaluated.
3. Water Buoyancy Loads. Water buoyancy loads shall be analyzed for buried structures with inverts below the water table.

B. Vehicular Loads

1. Wheel Loads. Where depth of fill is greater than 2 feet, wheel loads may be considered uniformly distributed over a rectangular area equal to the dimensions of the tire contact area.

   For depth of fill 2 feet or less, wheel loads shall be increased by 1.15 times the depth of fill in select granular backfill, and by 1.0 times the depth of the fill in all other cases.

2. Recreational Trails. The minimum design vehicular loading for buried structures supporting recreational trails shall accommodate maintenance traffic. The minimum design loading shall be H-15.

3. All Other Traffic. Buried structures below traffic other than recreational traffic shall be designed for vehicular loadings of HS-20 or higher.

4. Sidewalks. A pedestrian load of 85 psf shall be applied to all sidewalks, where warranted for location above buried structures, wider than 2 feet and considered simultaneously with vehicular design live load.

C. Tolerable Movement

The function and type of structure, anticipated service life, and consequences of unacceptable movement shall dictate the tolerable movement criteria for a buried structure.

D. Embankment Installation

The soil envelope shall be wide enough to ensure lateral restraint for the buried structure. In no case shall the width of the soil envelope on each side of the buried structure be less than the values specified in **Table 11-6.**

Table 11-6
Minimum Width of Soil Envelopes

Diameter, S (Inches)	Minimum Envelope Width (Feet)
<24	S/12
24–144	2.0
>144	5.0

E. Minimum Soil Cover

The depth of cover of a well compacted granular sub-base, taken from the top of rigid pavement or the bottom of flexible pavement shall be no less than the values specified in **Table 11-7 and Table 11-8.**

Table 11-7
Minimum Soil Cover for Buried Structures

Type	Condition	Minimum Cover
Structural Plate Pipe Structures		S/8≥12.0 inches
Long Span Structural Plate Pipe Structures		Refer to Table 11-8
Structural Plate Box Structures		1.4 to 5.0 ft.
Reinforced Concrete Pipe	Unpaved areas and under flexible pavement	B_c/8 or B'_c/8, (whichever is greater) ≥ 12.0 inches
	Compacted granular fill under rigid pavement	9.0 inches
Thermoplastic Pipe		ID/8 ≥ 12.0 inches

Notes for Table 11-7:

S = diameter of pipe (inches)
B_c = outside diameter or width of the structure (feet)
B'_c = out-to-out vertical rise to pipe (feet)
ID = inside diameter (inches)

Table 11-8
Minimum Soil Cover for Buried Long Span Plate Pipe Structures

	Minimum Cover, Feet				
Top Radius, ft:	**≥15.0**	**15 - 17**	**17 - 20**	**20 - 23**	**23 - 25**
Steel Thickness Without Ribs, inches					
.111	2.5	-	-	-	-
.140	2.5	3.0	-	-	-
.170	2.5	3.0	3.0	-	-
.188	2.5	3.0	3.0	-	-
.218	2.0	2.5	2.5	3.0	-
.249	2.0	2.0	2.5	3.0	4.0
.280	2.0	2.0	2.5	3.0	4.0

F. Minimum Pipe Spacing

Multiple lines of pipe shall be spaced far enough apart to permit proper placement and compaction of backfill below the haunch and between structures. Minimum spacing shall not be less than that shown in **Table 11-9**. The utility companies may have other spacing requirements that will use spacing greater than these requirements.

Table 11-9
Minimum Pipe Spacing

Type of Structure	Minimum Distance Between Pipes (Ft)
Round Pipes Diameter, D (ft)	
≤ 2.0	1.0
2.0 – 6.0	D/2
≥ 6.0	3.0
Pipe Arches Span, S (ft)	
≤ 3.0	1.0
3.0 – 9.0	S/3
9.0 – 16.0	3.0
Arches Span, S (ft)	
All Spans	2.0

11.5.3 Structural Plate Box Structures

Structural plate box culverts are composite reinforced rib plate structures rectangular in shape. These structures are relatively flat on top and require a large flexural capacity. Structural plate box culverts are also called metal box culverts.

A. Design

The shallow covers and extreme shapes of box culverts require special design procedures. Flexural requirements of metal box culverts govern the choice of section in all cases.

B. Geometric Requirements

See **Figure 11-6** and **Table 11-10** for geometric requirements for structural plate box structures.

Table 11-10
Geometric Requirements For Structural Plate Boxes

Parameter	Required Range
Span, S	8'-9" to 25'-5"
Rise, R	2'-6" to 10'-6"
Radius of crown, rc	< 24'-9 1/2"
Radius of haunch, rh	> 2'-6"
Haunch radius included angle, Δ	50 to 70 degrees
Length of leg, D (measured to the bottom of the plate)	4-3/4" to 71"
Minimum length of rib of leg, L	19"; D - 3"; or within 3" of top or footing (which ever is lowest)

C. Embankment Installation

The combined width of the soil envelope and embankment beyond shall be adequate to support all the loads on the culvert.

D. Live Loads

Live load distribution for culvert tops may be based on provisions for deck slabs spanning parallel to traffic.

E. Maximum Soil Cover

Maximum soil cover for structural plate box structures shall be limited to a depth of cover of 5 feet.

F. Concrete Relieving Slabs

Concrete relieving slabs may be used to reduce flexural moments in box culverts. The length of the concrete relieving slab shall project at least 1 foot beyond the haunch on each side of the culvert.

11.5.4 Reinforced Concrete Pipe

This section covers buried precast reinforced concrete pipes of circular, elliptical, and arch shapes.

A. Design

Buried reinforced concrete pipes shall be designed to resist structural failure due to flexure, thrust, shear, and radial tension. The dimensions of the pipe sections shall be determined with either the direct or indirect design method as outlined in the **AASHTO** standards referenced in **Section 11.1.1** .

B. Trench and Embankment Installations

Both trench and embankment installations shall be designed for embankment (positive projecting) loads and pressure distribution. The earth pressure distribution shall be the Hedger pressure distribution as shown in **Figure 11-7** and

Table 11-11.

Table 11-11
Coefficients for Use with Figure 11-7

	Installation Type			
Coefficient	**1**	**2**	**3**	**4**
VAF	1.35	1.4	1.4	1.45
HAF	0.45	0.4	0.37	0.3
A1	0.62	.85	1.05	1.45
A2	0.73	0.55	0.35	0.0
A3	1.35	1.4	1.4	1.45
A4	0.19	0.15	0.1	0.0
A5	0.08	0.08	0.1	0.11
A6	0.18	0.17	0.17	0.19
a	1.4	1.45	1.45	1.45
b	0.4	0.4	0.36	0.3
c	0.18	0.19	0.2	0.25
e	0.08	0.1	0.12	0.0
f	0.05	0.05	0.05	–
u	0.8	0.82	0.85	0.9
v	0.8	0.7	0.6	–

C. Live Loads

For standard installations, the live load on the pipe shall be assumed to have a uniform vertical distribution across the top of the pipe and the same distribution across the bottom of the pipe as shown in **Figure 11-7**.

11.5.5 Reinforced Concrete Cast-in-Place, Precast Box Culverts, and Reinforced Cast-in-Place Arches

This section covers cast-in-place and precast reinforced concrete box culverts and cast-in-place reinforced concrete arches.

A. Trench and Embankment Installations

Installations of trenches or embankments shall be constructed according to requirements in **Chapter 5, Soils Investigations and Report,** and **Chapter 22, Construction Specifications**.

B. Other Installations

Other installation methods (such as partial positive projection, 0.0 projection, negative projection, induced trench, and jacked installations) may be used to reduce the loads on a culvert.

C. Live Loads

1. Vehicular. All vehicular box culverts shall be designed for vehicular loadings of HS-20 or higher.
2. Less Than 2 Feet of Soil Cover. Distribution of wheel loads and concentrated loads for culverts with less than 2 feet of cover shall be as specified for slab-type

superstructures. Minimum cover shall be as required in **Chapter 12, Utility Locations**.

3. When Live Load Effects Can Be Ignored. For single-span culverts, the effects of live load may be neglected where the depth of fill is more than 8 feet and exceeds the span length. For multiple span culverts, the effects of live load may be neglected when depth of fill exceeds the distance between faces of end walls.

4. No Soil Cover. If soil cover is not provided, the top of reinforced concrete box structures shall be designed for direct application of vehicular and pedestrian loads.

D. Crack Width Control

Steel reinforcement shall be well distributed over the zone of maximum concrete tension to control flexural cracking.

11.5.6 Thermoplastic Pipe

This section covers buried thermoplastic pipe with solid, corrugated, or profile wall and constructed of High Density Polyethylene (HDPE) or Polyvinyl Chloride (PVC).

A. Design

Buried thermoplastic pipes under roadways and driveways shall be designed to resist structural failure due to thrust and buckling. Investigation of buckling shall be based on the 100-year value for modulus of elasticity.

B. Localized Distortion

Maximum localized distortion of installed plastic pipe shall be based on the service requirements outlined by **AASHTO** standards referenced in **Section 11.1.1** and overall stability of the installation.

C. Temporary Roadways

The design requirements for thermoplastic pipe may be relaxed for temporary roadways or special conditions as approved by the Local Entity Engineer.

11.5.7 Precast Reinforced Concrete Three-sided Structures

This section covers three-sided precast reinforced concrete structures supported on a concrete footing foundation.

A. Design

Design of three-sided structures shall be based on a pinned connection at the footing and shall take into account anticipated footing movement. Each precast three-sided structure shall be analyzed independently with no shear or stress transfer assumed between sections.

B. Geometric Requirements

The shape of precast three-sided structures, as specified by the manufacturer, may vary in span, rise, wall thickness, haunch dimensions, and curvature. Wall thickness shall be a minimum of 8.0 inches for spans under 24 feet and 10 inches for spans 24 feet and longer.

C. Shear Key

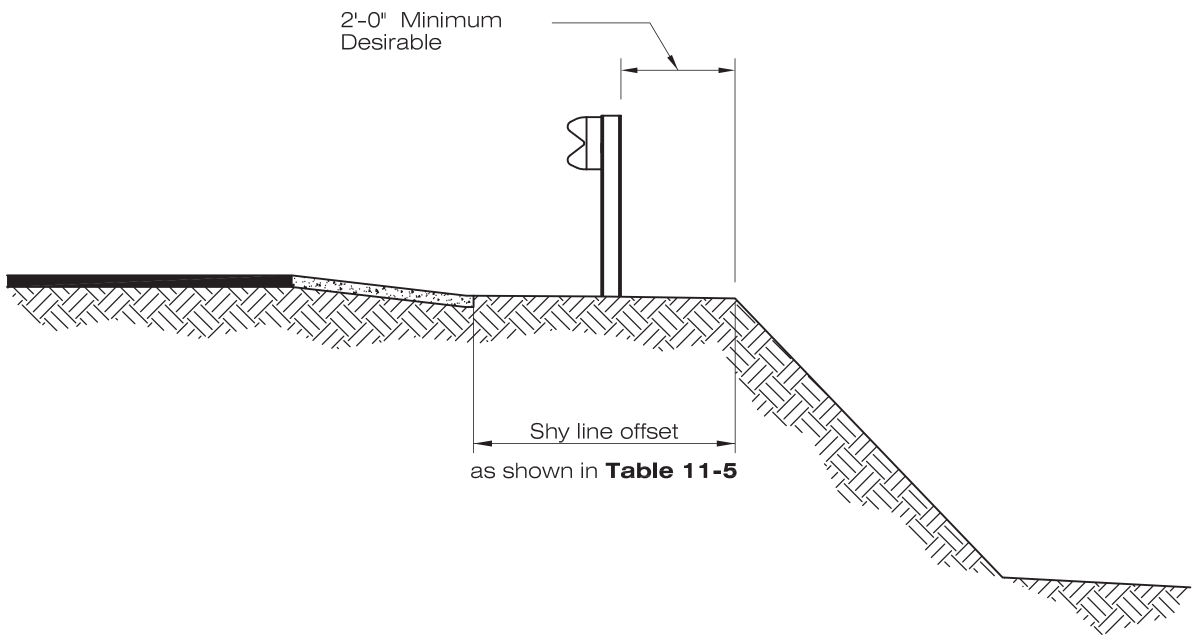
Flat top structures with shallow cover may experience differential deflection of adjacent units; therefore, shear keys shall be provided in the top surface.

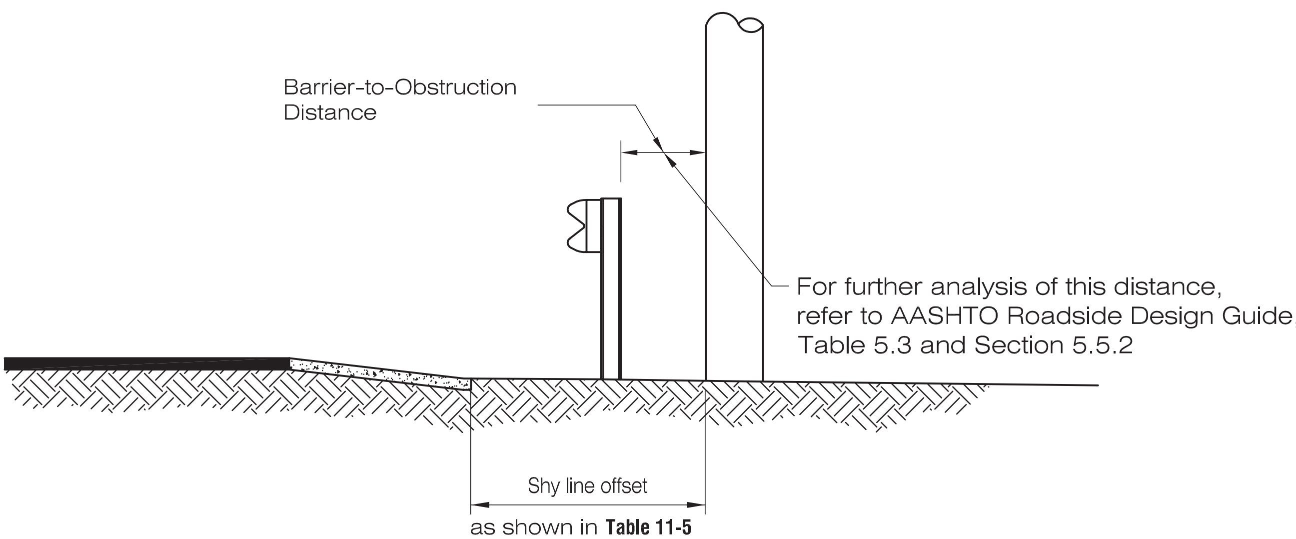
D. Minimum Reinforcement

The flexural reinforcement in the direction of span shall provide a ratio of reinforcement/gross concrete area ≥ 0.002. This minimum reinforcement shall be provided at all cross-sections subject to flexural tension, at the inside face of walls, and in each direction at the top of slabs of three-sided sections with less than 2.0 feet of fill.

E. Deflection Control

Deflection criteria shall be addressed in the design of all precast reinforced concrete three-sided structures.





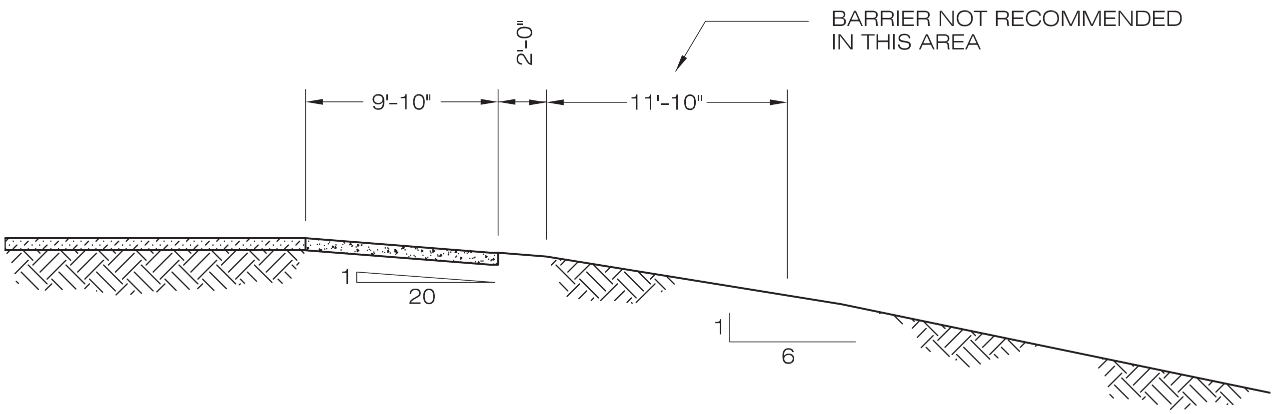
RECOMMENDED BARRIER PLACEMENT
FOR OPTIMUM PERFORMANCE

FROM AASHTO ROADWAY GUIDELINE

NOTE: This drawing has been converted from metric to English units.

RECOMMENDED BARRIER PLACEMENT

LARIMER COUNTY URBAN AREA STREET STANDARDS	DESIGN FIGURE	REVISION NO: DATE: 08/07/00	FIGURE 11-1



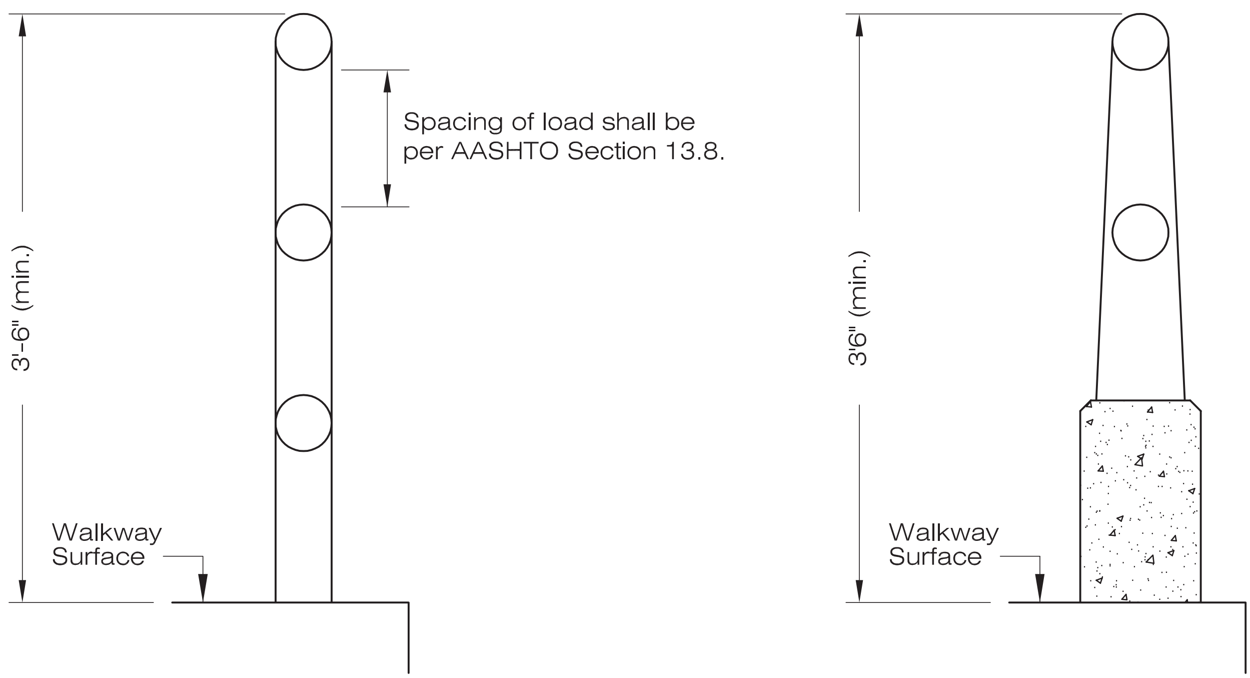
RECOMMENDED BARRIER PLACEMENT
FOR OPTIMUM PERFORMANCE

FROM AASHTO ROADWAY GUIDELINE

NOTE: This drawing has been converted from metric to English units.

RECOMMENDED BARRIER PLACEMENT

LARIMER COUNTY URBAN AREA STREET STANDARDS	DESIGN FIGURE	REVISION NO: DATE: 08/07/00	FIGURE 11-2

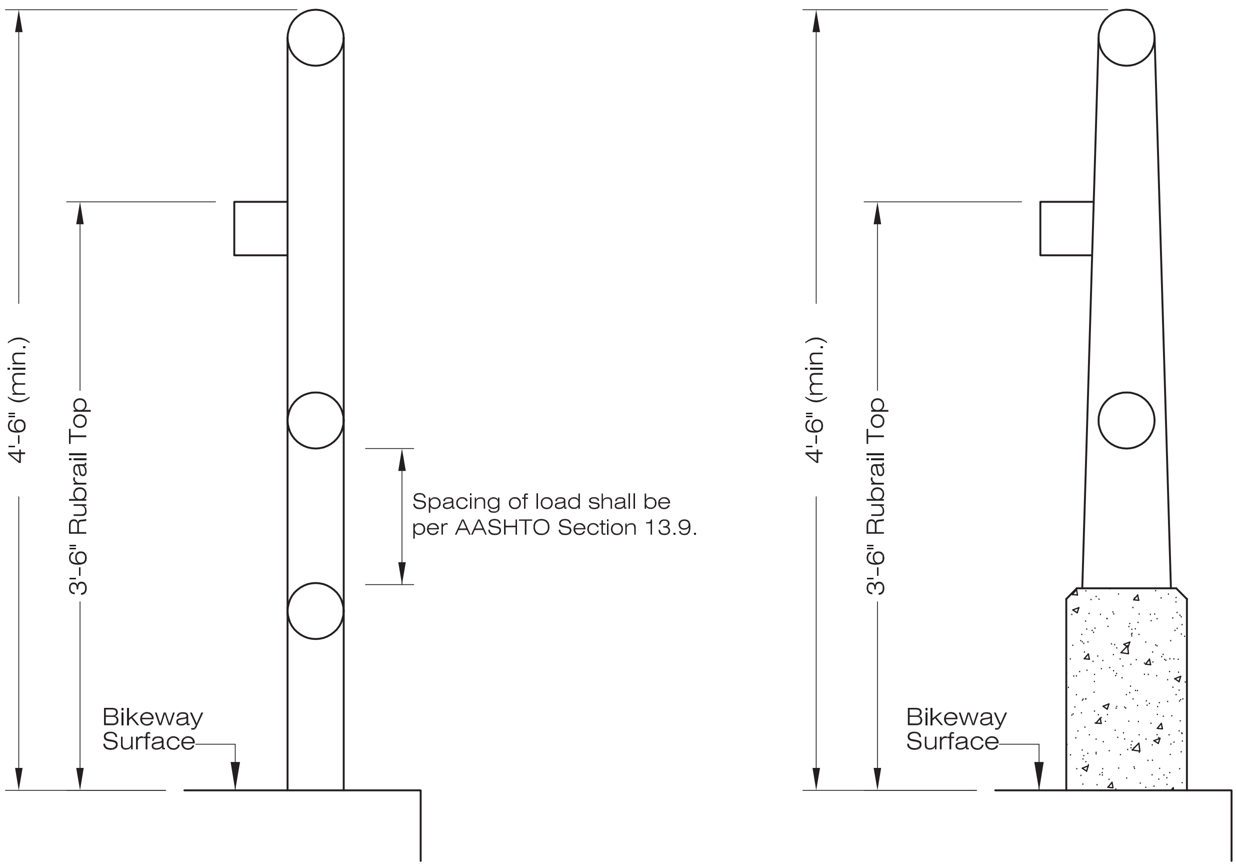


NOTE: To be used on the outer edge of a sidewalk when traffic is separated from pedestrian traffic by a traffic railing. Railing shape illustrative only.

FROM AASHTO ROADWAY GUIDELINE

PEDESTRIAN RAILING LOADS

LARIMER COUNTY URBAN AREA STREET STANDARDS	DESIGN FIGURE	REVISION NO:	FIGURE
		DATE: 08/07/00	11-3

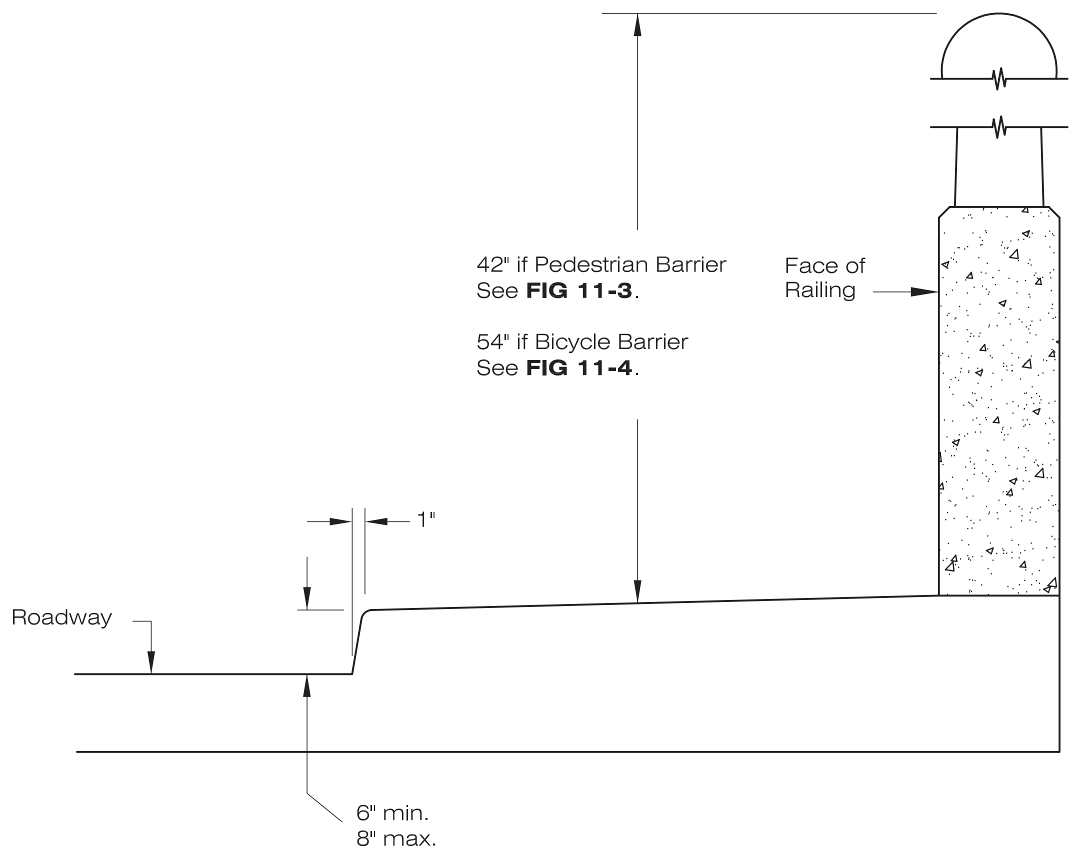


NOTE: To be used on the outer edge of a bikeway when traffic is separated from bicycle traffic by a traffic railing. Railing shape illustrative only.

FROM AASHTO ROADWAY GUIDELINE

BICYCLE RAILING LOADS

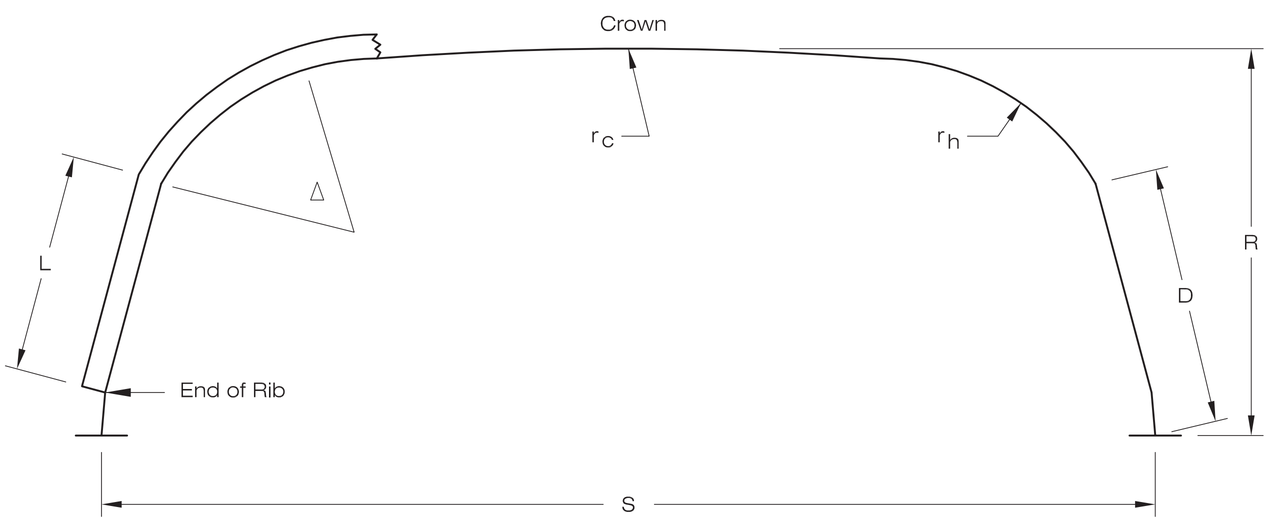
LARIMER COUNTY URBAN AREA STREET STANDARDS	DESIGN FIGURE	REVISION NO: DATE: 08/07/00	FIGURE 11-4



FROM AASHTO ROADWAY GUIDELINE

COMBINATION VEHICLE, PEDESTRIAN, BICYCLE BARRIER

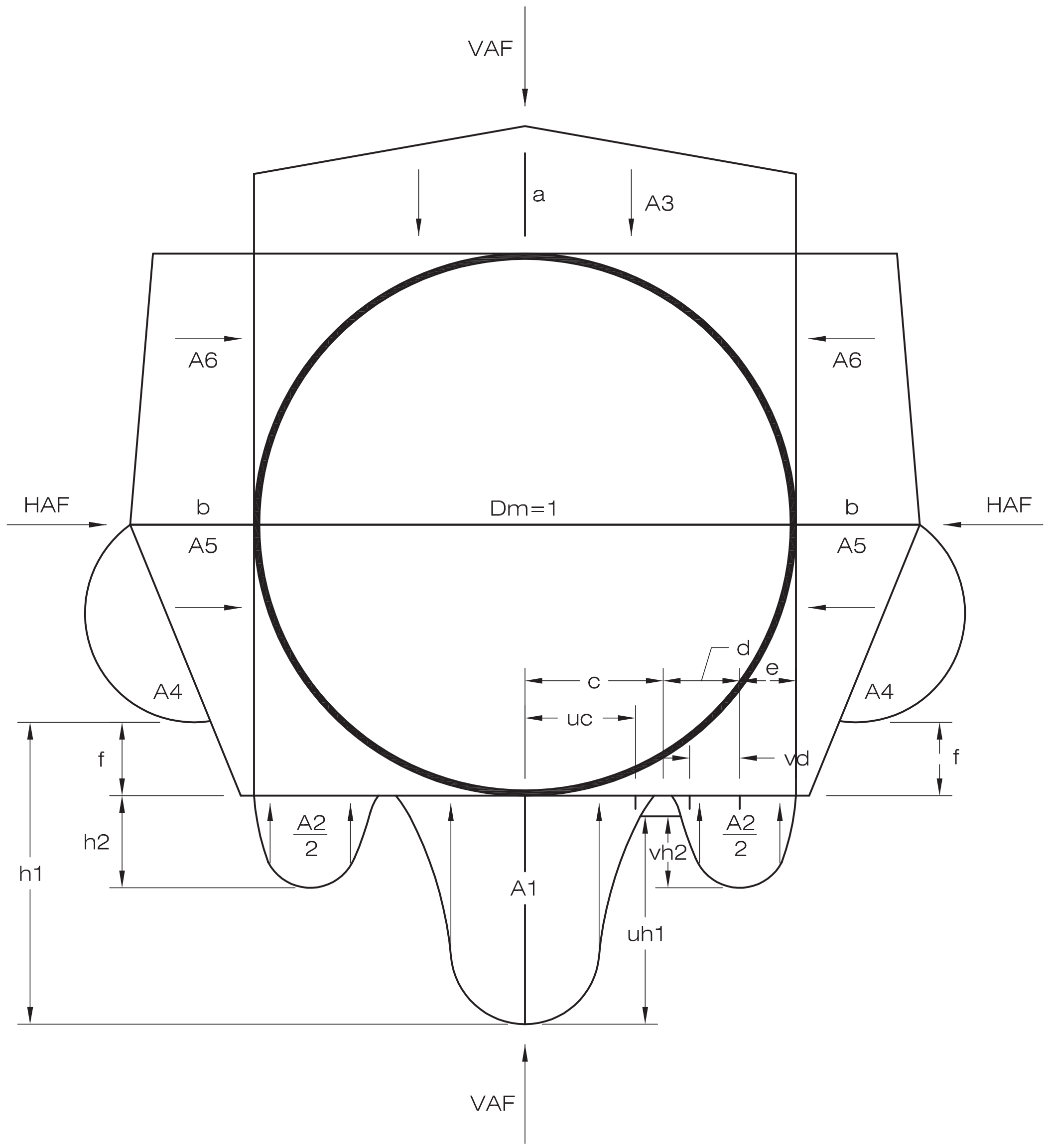
LARIMER COUNTY URBAN AREA STREET STANDARDS	DESIGN FIGURE	REVISION NO:	FIGURE
		DATE: 08/07/00	11-5



FROM AASHTO ROADWAY GUIDELINE

STRUCTURAL PLATE BOX GEOMETRIC REQUIREMENTS

LARIMER COUNTY URBAN AREA STREET STANDARDS	DESIGN FIGURE	REVISION NO: DATE: 08/07/00	FIGURE 11-6



NOTES:

1. VAF and HAF are vertical and horizontal arching factors. These coefficients represent nondimensional total vertical and earth loads on the pipe, respectively. The actual total vertical and horizontal loads are (VAF) x (PL) and (HAF) x (PL), respectively, where PL is the prism load.

2. Coefficients A1 through A6 represent the integration of nondimensional vertical and horizontal components of soil pressure under the indicated portions of the component pressure diagrams, i.e., the area under the component pressure diagrams.

3. The pressures are assumed to vary either parabolicly or linearly, as shown in Figure 1, with the nondimensional magnitudes at governing points represented by h1, h2, uh1, vh2, a, and b.

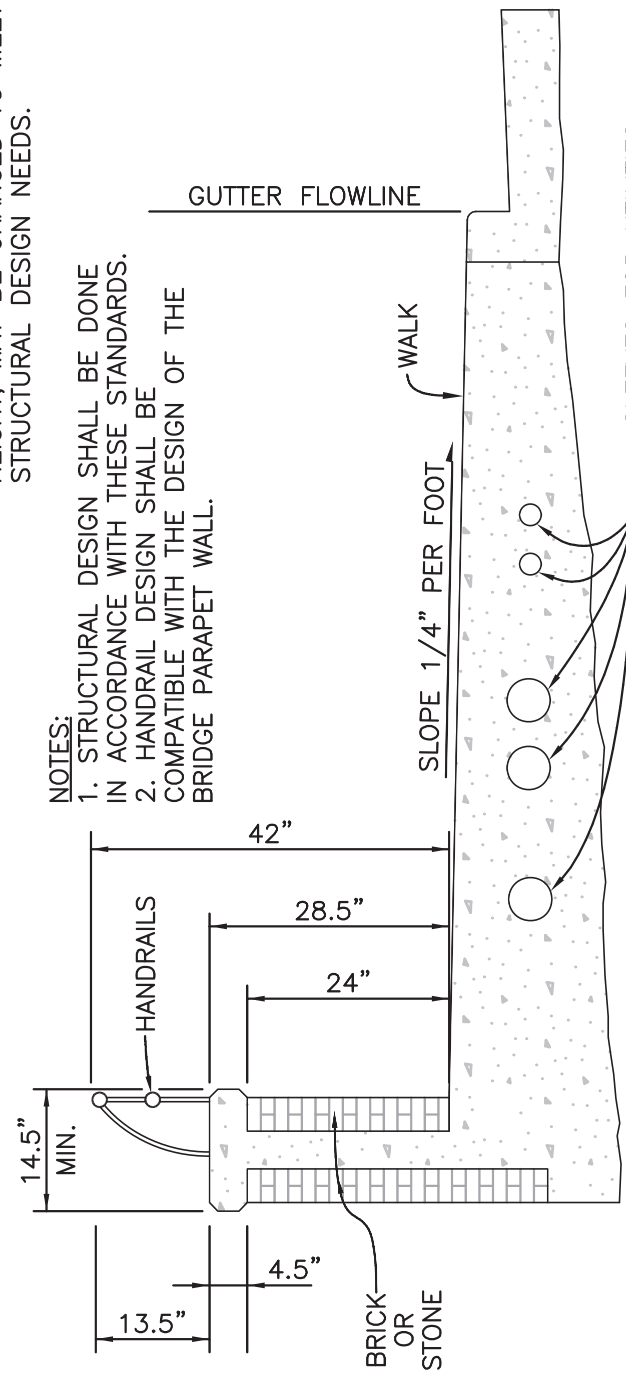
FROM AASHTO ROADWAY GUIDELINE

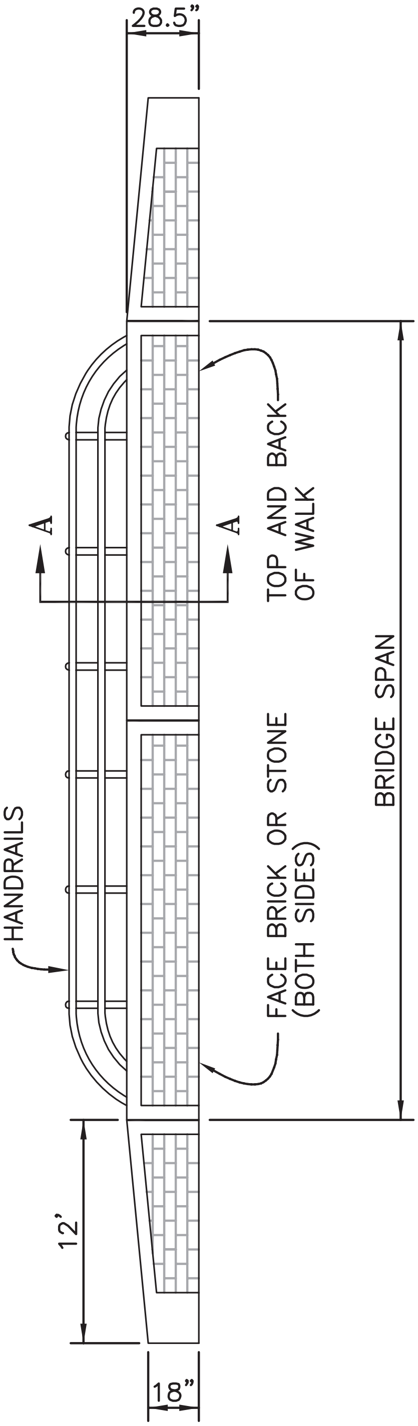
HEGER PRESSURE DISTRIBUTION & ARCHING FACTORS

LARIMER COUNTY URBAN AREA STREET STANDARDS	DESIGN FIGURE	REVISION NO: DATE: 08/07/00	FIGURE 11-7

THIS PLAN SPECIFIES APPEARANCE ONLY. THE STRUCTURE MUST BE DESIGNED TO FIT THE SPECIFIC CONDITIONS. DIMENSIONS ON THIS PLAN, EXCEPT FOR THE 42" RAILING HEIGHT, MAY BE CHANGED TO MEET STRUCTURAL DESIGN NEEDS.

<u>NOTES:</u>
1. STRUCTURAL DESIGN SHALL BE DONE IN ACCORDANCE WITH THESE STANDARDS.
2. HANDRAIL DESIGN SHALL BE COMPATIBLE WITH THE DESIGN OF THE BRIDGE PARAPET WALL.





<u>HEADWALL NOTES:</u>
1. PROVIDE MASONRY TIES FOR EACH BRICK COURSE.
2. ALL EXPOSED CONCRETE SHALL HAVE A RUBBED FINISH.

BRIDGE RAILING/PARAPET WALL CONFIGURATION DETAIL

LARIMER COUNTY URBAN AREA STREET STANDARDS	DESIGN FIGURE	REVISION NO: 2	FIGURE
		DATE: 04/01/07	11-8