MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter 11

Drainage and Irrigation Design

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Contents

Chapter 11

Drainage and Irrigation Design

Chapter 11 presents principles and criteria for the design and consideration of drainage facilities in collaboration with the roadway design; including:

- culverts,
- special-purpose large culverts,
- storm drains,
- roadside drainage,
- miscellaneous drainage facilities,
- irrigation facilities, and
- encasement pipes.

For detailed hydraulic design methods and policies, the *MDT Hydraulics Manual* is available at the following link on the MDT website and should be referenced in conjunction with the information in this chapter.

MDT Hydraulics Manual

The MDT Permanent Erosion and Sediment Control (PESC) Design Guidelines should also be referenced for an understanding of erosion control measures required with the design and implementation of drainage facilities. This manual is available at the following link on the MDT website.

The *MDT Permanent Erosion and Sediment Control Best Management Practices Manual* provides additional information on erosion control, primarily with regard to temporary conditions.

MDT Permanent Erosion and Sediment Control (PESC) Design Guidelines

Drainage design details are provided in the *MDT Detailed Drawings*, which are provided at the following link on the MDT website:

MDT Detailed Drawings

11.1 DESIGN PRINCIPLES AND APPROACH

Extensive coordination with the MDT Hydraulics Section should occur throughout the drainage design process.

Drainage facilities carry water across the right-of-way and remove stormwater from the roadway. Drainage facilities include bridges, culverts, channels, curbs, gutters, inlets, and various types of drains.

Drainage design is an integral component in the design of roadways and must be closely coordinated with other roadway design elements. There are many aspects that fall under the general category of drainage design. This chapter focuses heavily on design requirements and considerations in relation to culverts but also addresses a number of other drainage topics to be accounted for by the design team.

Live loads are the weight of an object (most commonly a vehicle) passing over a pipe. Earth loads are the weight of the material resting on top of the pipe.

Pipes may be fabricated out of many different types of material, and each of these materials presents different structural properties in response to both live loads and earth loads. The hydraulics designer will provide information for the different pipe material options, including wall thickness, size of corrugations, and class of concrete for all culverts larger than 24 inches in diameter. It is MDT's practice to specify alternate or optional pipe materials where they can be used, with the basic bid item for optional pipe being steel.

Pipes have different structural capabilities depending on the pipe size, both in terms of diameter and material thickness. In general, the smaller diameter the pipe and/or the thicker the pipe material the more load the pipe can withstand. The design team must be aware of these properties to ensure the fill heights fall within the maximum and minimum allowable ranges for the pipe material and size specified.

Pipe end treatments exist along the roadside and may result in a roadside hazard if not properly located and designed. The proper type of end treatment varies depending on the pipe size, shape, material, and orientation to the roadway. Inlet and outlet protection may also be specified at pipe ends in order to prevent erosion and maintain the integrity of the pipe and roadway.

Stormwater collection and conveyance occurs primarily through the use of storm drains and roadside drainage facilities. The detailed design of storm drains is prepared by the hydraulics designer. However, the design team is responsible for calculating the quantity of trunk line, granular bedding, and length of lateral lines and for checking for adequate cover over storm drain facilities. The storm drain design is an iterative process between Roadway Design Section and the hydraulics designer to establish a storm drain system that functions with the road grades, cross slopes, flow lines, and American with Disabilities Act (ADA) features.

For roadside drainage, the design team must ensure roadside drainage features are designed and constructed with consideration to the potential consequences of run-off-the-road vehicles. Refer to Chapter 9, Section 9.3.5 for detailed discussion on the design and safety considerations of roadside drainage features. Skewed pipes require special attention as the inside corners have the potential to be a roadside hazard.

Irrigation facilities must also be considered in the roadway design. Whenever possible, the design team should strive to locate longitudinal irrigation ditches outside of the right-of-way. The design team must coordinate with the hydraulics designer for all design details related to irrigation facilities.

This chapter also discusses several special-purpose large culverts and miscellaneous drainage features used for certain drainage design situations such as vehicular underpasses, stockpasses, and wildlife crossings. Additionally, coordination with the hydraulics designer may be required for special designs such as ditch blocks, interceptor ditches and dikes, streambank protection, detention basins, and retention basins.

11.2 CULVERTS

Nearly all drainage and irrigation facilities involve the use of some type of culvert. Culvert design requires a determination of:

- pipe material,
- design service life,
- pipe size and shape,
- pipe length,
- structural and installation requirements,
- pipe end treatments,
- pipe inlet and outlet edge protection, and
- pipe bedding/foundation.

11.2.1 Pipe Material

Pipes may be fabricated from concrete, steel, smooth steel casing (jacked and bored), aluminum, or plastic material. Pipe material selection will be based on an evaluation of the project location's soil and water corrosive characteristics. The hydraulics designer will provide recommendations for the different pipe material options including wall thickness, size of corrugations, coating, and class of concrete for all culverts larger than 24" in diameter or equivalent.

11.2.1.1 Common Pipe Materials

The pipe materials listed in Exhibit 11-1 are commonly used by MDT. Pipe material selection for mainline culvert crossings, approach culverts, irrigation facilities, and storm drains is based on design criteria such as service life, site conditions, and its intended use. The pipe materials in Exhibit 11-1 are not intended to be all inclusive; therefore, a proper engineering analysis is required for all installations. For large installations, the analysis should include installation cost comparisons.

Exhibit 11-1
Pipe Materials

Pipe Material	Abbreviation	AASHTO Specification	MDT Specification
Corrugated Steel Pipe*	CSP	M36	709.02
Corrugated Steel Pipe Arch*	CSPA	M36	709.02
Structural Steel Plate Pipe**	SSPP	M167	709.03
Structural Steel Plate Pipe Arch**	SSPPA	M167	709.03
Reinforced Concrete Pipe	RCP	M170	708.01.2
Reinforced Concrete Pipe Arch	RCPA	M206	708.01.3
Reinforced Concrete Box	RCB	M259 M273	Standard Special Provision 603-3
Corrugated Aluminum Pipe	CAP	M196	709.07
Steel Casing Pipe	SCP	--	709.01.2***
Corrugated Polyethylene Pipe	HDPE	M294	708.07

* Acceptable coatings:	-Type II Aluminized	AASHTO M274	MDT 709.12
	-Pre-Coated Polymeric	AASHTO M245	MDT 709.05
** Acceptable coatings:	-Bituminous	AASHTO M243	MDT 709.04

***Other steel grades may be allowed on a case by case basis.

For reconstruction projects where existing pipes can be used in place and require lengthening, the additional length of pipe usually will be constructed of the same material as the existing pipe. Pipes to be lengthened will be identified in the hydraulics designer recommendations.

11.2.1.2 Alternative/Optional Pipe Materials

The basic bid item for optional pipe is steel. If steel pipe is not an option in the design, then reinforced concrete pipe (RCP) will be the basic bid item. MDT requires consideration of all available non-proprietary pipe products that are judged to be of satisfactory quality and equally acceptable on the basis of engineering properties and economic analysis. When products appear to be equal, alternative or optional bidding practices are used. Alternative bids will be used for SSPP and RCB when the area of the opening is greater than a 10 foot diameter round pipe and the use of both materials is appropriate. Alternate bids can be provided for small structures if the design team elects to do so.

Where alternative/optional products are determined to have different engineering and economic properties, based on the required engineering properties and/or life-cycle cost criteria, the hydraulics designer will document its material selection decision on a project or program basis as appropriate.

It is MDT's practice to specify alternate or optional pipe materials where they can be used. To qualify for selection, optional pipe materials must meet the following criteria:

- Provide adequate hydraulic capacity;
- Withstand forces of the weight of the fill over the pipe;
- Withstand forces of traffic loads and construction equipment during pipe installation and under post-construction conditions;
- Withstand hydrostatic pressure to prevent fluid from leaking in or out of the pipe into the surrounding bed materials;
- Provide adequate service life in relation to the Design Service Life guidelines provided in Section 11.2.2;
- Withstand corrosion caused by the fluids conveyed by the pipe and the soil surrounding the pipe;
- Withstand abrasion from solids carried by the flow;
- Withstand fire and combustion;
- Be constructible within the constraints of the site;
- Provide desired fish passage characteristics and meet other project based environmental requirements when required;
- Consider local government preferences; and
- Fulfill the need for experimental installations and/or the Materials Bureau product review process.

Culverts, storm drains, or other installations shall be studied on a case-by-case basis to determine if the optional materials satisfy these requirements.

11.2.2 Design Service Life

The hydraulics designer will use service life to determine the required wall thickness, type of coating, and any special requirements for new pipes. For each project, the hydraulics designer will evaluate the corrosive soil report, as provided by the Materials Bureau, to determine design service life and the allowable pipe materials. The remaining service life of existing culverts will guide the decision to either replace the culverts or use them in place. The culvert service life will comply with the following guidelines:

For specific design criteria, see the "Culvert Service Life Guidelines" as published in the *MDT Hydraulics Manual*.

- The design service life for new or replacement culverts will be:
  - 40 years for approach pipes*;
  - 75 years for mainline pipes;
  - 75 years for storm drains; and
  - For irrigation pipe and siphons, the life of the pipe is the time it takes for the first perforation to occur. Therefore, the design service life must be doubled (e.g., for design purposes a mainline

***Approach pipes will not receive any coating unless specifically recommended.**

irrigation crossing needs an effective life of 150 years life, and a minor irrigation approach pipe needs an effective life of 80 years).

- The design service life for overlay and minor widening projects will be 20 years for all in-place culverts.
- The design service life for pipes used in place on safety improvement or roadway widening projects will be:
    - 25 years for all in-place pipes except as follows;
    - 50 years for all pipes where any one of the following applies:
        - Fill heights are over 15 feet;
        - Average daily traffic (ADT) is greater than 5,000 vehicles per day;
        - Grade raises over 5 feet;
        - All 4-lane roadways; and/or
        - Extensions are greater than 50-percent of the in-place length of the culvert.

11.2.3 Pipe Size

The locations and sizes of existing pipes, as well as any problems with existing pipes, such as insufficient capacity, roadway overtopping, erosion, pipe damage, rusting/corrosion, or debris/ice obstruction, should be noted at the Preliminary Field Review.

All new mainline drainage pipes should be at least 24” in diameter. All new irrigation pipes and approach pipes should be at least 18” in diameter. Equivalent arch pipes may be used. If an approach pipe also carries irrigation water the design team should consult with the hydraulics designer to determine the appropriate pipe size.

The hydraulics designer will provide pipe size recommendations for drainage crossings requiring pipes greater than 24” in diameter or equivalent and for all irrigation crossings. The design team will determine the location of all minimum size drainage crossings and will design all inlet, outlet, and roadside ditches for positive drainage. The design team should keep in mind that many pipes, especially larger diameter pipes, are typically embedded below the flowline.

Occasionally, pipes may need to be oversized to account for environmental needs such as Aquatic Organism Passage (AOP), wildlife, or stock crossings based on the specific location. See Section 11.3 for discussion on special-purpose large culverts.

11.2.4 Pipe Length

Pipe length should be determined by measuring along the pipe flowline and should include any end treatments. If the pipe installation is perpendicular or skewed less than 5 degrees to the roadway centerline, then the pipe length may be scaled directly from the roadway cross section. If the pipe is skewed more than 5 degrees, scale its length along the skewed line.

When end sections are specified (such as FETS, RACETS, step bevel or beveled ends), measure the pipe length, including the end sections, along the pipe flowline. Additional pipe length is not required for the end sections. However, if the end treatment is square to the skewed pipe, the pipe must be extended beyond the toe of the slope, and additional pipe length is required to ensure the fill slope catches at the inside corner of the concrete edge protection. Chapter 13 provides additional information on measuring and quantifying pipe lengths.

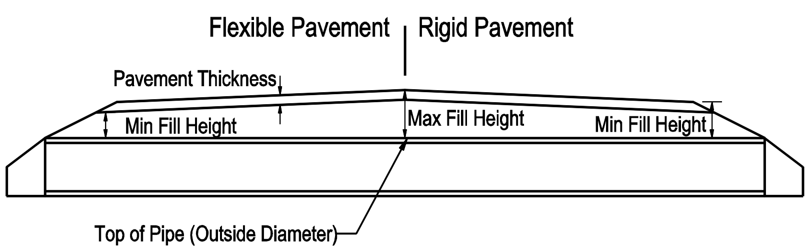
FETS = Flared End Terminal Section

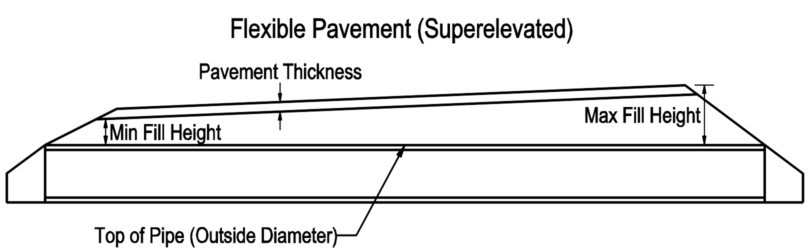
RACETS = Road Approach Culvert End Treatment Section

11.2.5 Structural Requirements for Pipes

Structural requirements for pipes are based primarily upon live-load and earth-load conditions. Maximum fill heights are set to protect the pipe structure from the earth load, and minimum fill heights are set to protect the pipe structure from live loads. Exhibit 11-2 illustrates the measurement of maximum and minimum fill heights for both flexible and rigid pavement sections. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness. Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement, and identified in the culvert summary frame. Consider using reinforced concrete pipe, equivalent sized arch pipe, or multiple smaller pipes where the minimum fill height cannot be provided using the basic bid pipe.

Exhibit 11-2
Measurement of Maximum and Minimum Fill Heights





11.2.5.1 Reinforced Concrete Pipe (RCP)

Reinforced Concrete Pipes (RCP) are identified by "class" numbers, depending on their respective strength characteristics. Four classes are available—Class 2, 3, 4, and 5; the higher the number, the stronger the pipe. Exhibit 11-3 provides maximum fill heights for RCP embankment installation. Exhibit 11-4 provides maximum fill heights for RCP trench installation. Exhibit 11-5 provides RCP minimum fill heights, which apply to either installation condition.

For Reinforced Concrete Pipe Arches (RCPA), use the fill height requirements for the equivalent diameter RCP. Exhibit 11-6 provides the equivalent RCP diameters for RCPA. RCPA are only available in Class 3 and 4.

Pipes should not extend into the surfacing section. Although not desirable, pipes may extend into the special borrow course.

Exhibit 11-3 Maximum Fill Heights for Reinforced Concrete Pipe (RCP) – Embankment Installation

Pipe Diameter (in)	RCP Maximum Fill Height* (ft) Embankment Installation			
	Pipe Class			
	Class 2	Class 3	Class 4	Class 5
12	**	15	22	33
18	**	15	22	33
24	**	15	22	33
30	11	15	22	33
36	11	15	22	33
42	11	15	22	33
48	11	15	22	33
54	11	14	22	33
60	10	14	21	33
66	10	14	21	32
72	10	14	21	32
78	10	14	21	32
84	10	14	21	32
90	10	14	21	32
96	10	14	21	32

* Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

** This class of pipe is not available in the sizes indicated.

Notes:

1. Embankment installation based on MDT Detailed Drawings 603-18 and 603-19
2. This fill height table was developed using the indirect design method detailed in the ACPA Concrete Pipe Design Manual, version 19. This table applies only to pipes having "B" wall thickness.
3. Special Design is required when fill heights exceed Class 5 fill heights shown in table above.
4. For RCPA, use maximum fill heights for equivalent RCP diameter listed above. RCPA is only available in Class 3 and 4.

Exhibit 11-4
Maximum Fill Heights for Reinforced Concrete Pipe (RCP) – Trench Installation

Pipe Diameter (in)	RCP Maximum Fill Height* (ft) Trench Installation			
	Pipe Class			
	Class 2	Class 3	Class 4	Class 5
12	**	15	22	33
18	**	15	22	33
24	**	15	22	33
30	11	15	22	33
36	11	15	22	33
42	11	15	22	33
48	11	15	22	33
54	12	17	29	33
60	12	17	29	33
66	12	17	29	32
72	12	17	29	32
78	12	17	29	32
84	12	17	29	32
90	12	17	29	32
96	12	17	29	32

* Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

** This class of pipe is not available in the sizes indicated.

Notes:

1. Trench installation based on bedding material placed to the springline of the pipe and trench width; equal to the outside pipe diameter, plus 3 feet.
2. This fill height table was developed using the indirect design method detailed in the ACPA Concrete Pipe Design Manual, version 19. This table applies only to pipes having "B" wall thickness.
3. Special design is required when fill heights exceed Class 5 fill heights shown in table above.
4. Class 5 fill heights are based on embankment conditions due to constructability.
5. For RCPA, use maximum fill heights for equivalent RCP diameter listed above. RCPA is only available in Class 3 and 4.

Exhibit 11-5
Minimum Fill Heights for Reinforced Concrete Pipe (RCP)

Pipe Diameter (in)	RCP Minimum Fill Height* (in)			
	Pipe Class			
	Class 2	Class 3	Class 4	Class 5
12	**	**	12	6
18	**	18	6	6
24	**	12	6	6
30	24	6	6	6
36	6	6	6	6
42	6	6	6	6
48	6	6	6	6
>48	6	6	6	6

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement at the lowest point of the paved portion of the cross section.

** This class of pipe should not be used for the size noted for minimum cover designs.

Notes:
1. For RCPA, use minimum fill heights for equivalent RCP diameter listed above. RCPA is only available in Class 3 and 4.
2. Pipes should not extend into the surfacing section. Although not desirable, pipes may extend into the special borrow course.

Exhibit 11-6
Reinforced Concrete Pipe Arches (RCPA) – Equivalent Diameters

Span (in)	Rise (in)	Equivalent Diameter (in)
22	13½	18
28½	18	24
36¼	22½	30
43¾	26⅝	36
51⅛	31 5/16	42
58½	36	48
65	40	54
73	45	60
88	54	72
102	62	84

Table values are from AASHTO Materials, Standard Specifications for Transportation Materials, Part 1, M206 & M206M *(2)*.

11.2.5.2 Corrugated Steel Pipe (CSP)

Metal thickness and soil support are the principal measures of strength in Corrugated Steel Pipe (CSP). The required metal thickness depends on the following factors:

- height of fill over pipe,
- dimensions of corrugations,
- shape of pipe,
- soil compaction,
- corner bearing pressure, and
- soil corrosiveness.

Exhibits 11-7 through 11-9 illustrate some of the relationships between these factors. The exhibits show the minimum and the maximum permissible fill heights for each combination of pipe size and metal thickness. Per the culvert fill height tables, pipes should be placed at a minimum of 0.3 feet to 1.0 foot below the surfacing subgrade. Although not desirable, pipes may extend into the special borrow course if necessary due to constraints. See the fill height exhibits for additional information.

Normally, for steel pipe installations up to 120″ in diameter, CSP will be specified for installation. The fill heights for these pipes must fall within the limits of the fill height exhibits.

The following corrugation sizes will be specified for steel pipe:

- 2 ⅔″ x ½″,
- 3″ x 1″, or
- 5″ x 1″.

The design team should note the corrugation sizes on the culvert summary.

Most culvert installations will be "round" pipe. Pipe arches are specified where cover is limited or where local conditions make the shape of the pipe arch more effective for carrying the water. Exhibits 11-10 and 11-11 present structural requirements for Corrugated Steel Pipe Arch (CSPA) culverts.

Exhibit 11-7 Structural Requirements for Corrugated Steel Pipe (CSP) (Welded or Lock Seam)

2 ⅔" x ½" Corrugations ①, ② *Welded or Lock-Seam Steel Pipe*						
Pipe Diameter (in)	Minimum Fill Height* (in)	Maximum Fill Height* (ft) Metal Thickness (in)				
		0.064	0.079	0.109	0.138	0.168
12	18	213	266			
18	18	142	177			
24	18	106	133	186		
30	18	85	106	149		
36	18	71	88	124	159	
42	18	60	76	106	137	167
48	18	53	66	93	119	146
54	18		59	82	106	130
60	18			74	95	117
66	18				87	106
72	18				79	97
78	18					90
84	18					83

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. For private approaches, see Exhibit 11-19 for alternate minimum fill height. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

For all pipes less than 84", the top of the pipe should be located a minimum of 0.3 feet below the bottom of the surfacing subgrade. For all pipes 84", and larger, the top of the pipe should be located a minimum of 1.0-foot below the surfacing subgrade.

Notes:

① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.

② For a given fill height, the wall thicknesses for both the 2 ⅔" x ½" and the 3" x 1" corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.

Exhibit 11-8
Structural Requirements for Corrugated Steel Pipe (CSP) (Welded or Lock Seam)

3” x 1” Corrugations ①, ② *Welded or Lock-Seam Steel Pipe*						
Pipe Diameter (in)	**Minimum Fill Height* (in)**	**Maximum Fill Height* (ft) Metal Thickness (in)**				
		0.064	**0.079**	**0.109**	**0.138**	**0.168**
54	18	54	68	95	122	150
60	18	49	61	85	110	135
66	18	44	55	78	100	122
72	18	40	51	71	92	112
78	18	37	47	66	85	104
84	18		43	61	78	96
90	18		40	57	73	90
96	18			53	69	84
102	18			50	65	79
108	18			47	61	75
114	18				58	71
120	18				55	67

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

For all pipes less than 84”, the top of the pipe should be located a minimum of 0.3 feet below the bottom of the surfacing subgrade. For all pipes 84”, and larger, the top of the pipe should be located a minimum of 1.0-foot below the surfacing subgrade.

Notes:

① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.

② For a given fill height, the wall thicknesses for both the 2 ⅔” x ½” and 3” x 1” corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.

Exhibit 11-9 Structural Requirements for Corrugated Steel Pipe (CSP) (Welded or Lock Seam)

5” x 1” Corrugations ① *Welded or Lock-Seam Steel Pipe*						
Pipe Diameter (in)	**Minimum Fill Height* (in)**	**Maximum Fill Height* (ft) Metal Thickness (in)**				
		0.064	**0.079**	**0.109**	**0.138**	**0.168**
54	18	48	60	84	109	133
60	18	43	54	76	98	120
66	18	39	49	69	89	109
72	18	36	45	63	82	100
78	18	33	42	58	75	92
84	18		39	54	70	85
90	18		36	51	65	80
96	18			47	61	75
102	18			45	57	70
108	18			42	54	66
114	18				51	63
120	18				49	60

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

For all pipes less than 84”, the top of the pipe should be located a minimum of 0.3 feet below the bottom of the surfacing subgrade. For all pipes 84”, and larger, the top of the pipe should be located a minimum of 1.0-foot below the surfacing subgrade.

Notes:

① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.

② 5”x1” corrugations are not typically used; however, in some instances, manufacturers may recommend 5”x1” corrugations in order to provide polymeric coating on thicker gage pipes.

Exhibit 11-10
Structural Requirements for Corrugated Steel Pipe Arch (CSPA)

2 ⅔" x ½" Corrugations *Steel Pipe Arch (All Seam Fabrications)*							
Pipe Dimensions Span x Rise (in)	Equiv. Diameter (in)	Min. Fill Height* (in)	Maximum Fill Height* (ft)① Minimum Metal Thickness (in)②				
			0.064	0.079	0.109	0.138	0.168
21 x 15	18	24	9**				
28 x 20	24	24	10				
35 x 24	30	30	7				
42 x 29	36	30	7				
49 x 33	42	36		7			
57 x 38③	48	24			8		
64 x 43③	54	24			9		
71 x 47③	60	24				10	
77 x 52③	66	24					10
83 x 57③	72	24					10

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

For all pipe 2 $^{2}/_{3}$" x $^{1}/_{2}$" corrugations, the top of the pipe should be located a minimum of 0.3 feet below the surfacing subgrade.

Notes:

① Based upon a 3-ton corner bearing pressure except as noted (**). Special foundation investigation required.

** Based upon a 2-ton corner bearing pressure. Special foundation investigation required when higher corner bearing pressures need to be developed.

② Thicknesses above the heavy line will not be used unless specified by the hydraulics designer.

③ These sizes should not be used unless site conditions preclude the use of arches with 3" x 1" corrugations.

Exhibit 11-11 Structural Requirements for Corrugated Steel Pipe Arch (CSPA)

3” x 1” or 5” x 1” Corrugations
Steel Pipe Arch (All Seam Fabrications)

Pipe Dimensions** Span x Rise (in)	Equiv. Dia. (in)	Min. Fill Height* (in)	Maximum Fill Height* (ft) ① Minimum Metal Thickness (in)				
			0.064	0.079	0.109	0.138	0.168
53 x 41	48	24		8③			
60 x 46	54	24		9③			
66 x 51	60	24		9③			
73 x 55	66	24		11③		②	
81 x 59	72	24		11③			
87 x 63	78	24		10③			
95 x 67	84	24		11③			
103 x 71	90	24			10		
112 x 75	96	24			10		
117 x 79	102	24			10		
128 x 83	108	24				9	

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

For all pipe arches less than 95” x 67”, the top of the pipe should be located a minimum of 0.3 feet below the surfacing subgrade. For all pipe arches 95” x 67” and larger, the top of the pipe should be located a minimum of 1.0 feet below the surfacing subgrade.

** Nominal dimensions per manufacturers’/suppliers’ product information.

Notes:

① Based upon a 2-ton corner bearing pressure. Special foundation investigation required when higher corner bearing pressures need to be developed.

② Thicknesses above the heavy line will not be used unless specified by the hydraulics designer.

③ Specify 0.109” thickness for 5” x 1” corrugations.

11.2.5.3 Structural Steel Plate Pipes (SSPP)

Normally, for culvert installations larger than 120”, Structural Steel Plate Pipe (SSPP) culverts will be specified. Exhibit 11-12 provides SSPP criteria for minimum and maximum fill heights permitted with various combinations of pipe size and metal thickness. The hydraulics designer will specify adequate metal thickness for each installation of SSPP. The dimension of SSPP will be called out in feet and inches. Exhibits 11-13 and 11-14 present the structural requirements for Structural Steel Plate Pipe Arch (SSPPA) culverts.

Exhibit 11-12
Structural Requirements for Structural Steel Plate Pipes (SSPP)

6” x 2” Corrugations
Structural Steel Plate Pipe

Pipe Diameter**	Min. Fill Height* (in)	Maximum Fill Height* (ft)① Minimum Metal Thickness (in)						
		0.109	**0.138**	**0.168**	**0.188**	**0.218**	**0.249**	**0.280**
5’-0”	18	47	68	90	103	124	146	160
6’-0”	18	39	57	75	86	103	122	133
7’-0”	18	34	49	64	73	88	104	114
8’-0”	18	29	43	56	64	77	91	100
9’-0”	18	26	38	50	57	69	81	88
10’-0”	18	23	34	45	51	62	73	80
11’-0”	18	21	31	40	47	56	66	72
12’-0”	18	19	28	37	43	51	61	66
13’-0”	20	18	26	34	39	47	56	61
14’-0”	24	17	24	32	36	44	52	57
15’-0”	24	15	23	30	34	41	48	53
16’-0”	24		21	28	32	38	45	50
17’-0”	28		20	26	30	36	43	47
18’-0”	28			25	28	34	40	44
19’-0”	32			23	27	32	38	42
20’-0”	32				25	31	36	40
21’-0”	32					29	34	38

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

For all pipes less than 7’-0”, the top of the pipe should be located a minimum of 0.3 feet below the bottom of the surfacing subgrade. For all pipes 7’-0”, and larger, the top of the pipe should be located a minimum of 1.0-foot below the surfacing subgrade.

** Nominal diameters per manufacturers’/suppliers’ product information.

Notes:

① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.

Exhibit 11-13 Structural Requirements for Structural Steel Plate Pipe Arch (SSPPA)

SSPPA, 6” x 2” Corrugations

18” Corner Radius ①

Pipe Dimensions② Span x Rise	Minimum Fill Height* (in)	Maximum Fill Height* (ft)③ Minimum Metal Thickness (in)
		0.109
6’-1” x 4’-7”	24	16
6’-4” x 4’-9”	24	15
7’-0” x 5’-1”	24	14
7’-3” x 5’-3”	24	13
7’-8” x 5’-5”	24	13
8’-2” x 5’-9”	30	12
8’-10” x 6’-1”	30	11
9’-9” x 6’-7”	30	10
10’-8” x 6’-11”	30	9
10’-11” x 7’-1”	30	9
11’-10” x 7’-7”	36	7
12’-8” x 8’-1”	36	6
12’-10” x 8’-4”	48	6
13’-5” x 8’-5”	48	5

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

For all SSPPA pipes, the top of the pipe should be located a minimum of 1.0-foot below the surfacing subgrade.

Notes:

① These sizes should not be specified unless site conditions preclude the use of CSPA or SSPPA with 31-inch corner radii.

② Intermediate sizes not listed have the same maximum and minimum fill heights and metal thicknesses as the next larger size listed in this table.

③ Based upon a 2-ton corner bearing pressure. Special foundation investigation required when higher corner bearing pressures need to be developed.

Exhibit 11-14
Structural Requirements for Structural Steel Plate Pipe Arch (SSPPA)

SSPPA, 6” x 2” Corrugations *31” Corner Radius*					
Pipe Dimensions① Span x Rise (in)	**Minimum Fill Height* (in)**	**Maximum Fill Height* (ft)② Minimum Metal Thickness (in)**			
		0.109	**0.138**	**0.168**	**0.188**
13'-6" x 9'-6"	30	12			
14'-2" x 9'-10"	30	12			
15'-7" x 10'-6"	30	11			
15'-10" x 10'-8"	30		10		
17'-2" x 11'-4"	30		10		
17'-11" x 11'-8"	30			9	
18'-1" x 11'-10"	30			9	
18'-9" x 12'-2"	36			9	
19'-11" x 12'-10"	36				7
20'-7" x 13'-2"	36				7

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

For all SSPPA pipes, the top of the pipe should be located a minimum of 1.0 foot below the surfacing subgrade.

Notes:

① Intermediate sizes not listed have the same maximum and minimum fill heights and metal thicknesses as the next larger size listed in this table.

② Based upon a 2-ton corner bearing pressure. Special foundation investigation required when higher corner bearing pressures need to be developed.

11.2.5.4 Corrugated Aluminum Pipe (CAP)

When Corrugated Aluminum Pipe (CAP) is specified or permitted as an option, determine the metal thickness requirements from Exhibits 11-15 or 11-16 for the particular conditions of pipe shape and height of fill.

Exhibit 11-15 Structural Requirements for Corrugated Aluminum Pipe (CAP) (Lock Seam Aluminum)

2 ⅔" x ½" *Corrugations* ①, ②, ③
Lock-Seam Aluminum Pipe

Pipe Diameter (in)	Minimum Fill Height* (in)	Maximum Fill Height* (ft) Metal Thickness (in)				
		0.060	0.075	0.105	0.135	0.164
12	18	113	142			
18	18	75	94			
24	18	56	71	99		
30	18		56	79		
36	18		47	66	85	
42	18			56	73	
48	18			49	63	78
54	18			43	56	69
60	18				50	62
66	18					56
72	18					45

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

For all aluminum pipes, the top of the pipe should be located a minimum of 0.3 feet below the surfacing subgrade.

Notes:

① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.

② For a given fill height, the wall thicknesses for both the 2 ⅔" x ½" and 3" x 1" corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.

③ Fill heights taken from manufacturers'/suppliers' product information.

Exhibit 11-16
Structural Requirements for Corrugated Aluminum Pipe (CAP) (Lock Seam Aluminum)

3” x 1” *Corrugations* ①, ②, ③ *Lock-Seam Aluminum Pipe*						
Pipe Diameter (in)	Minimum Fill Height* (in)	Maximum Fill Height* (ft) Metal Thickness (in)				
		0.060	0.075	0.105	0.135	0.164
30	18	52	65	91		
36	18	43	54	76	98	
42	18	36	46	65	84	
48	18	32	40	57	73	90
54	18	28	35	50	65	80
60	18		32	45	58	72
66	18		28	41	53	65
72	18		26	37	48	59

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

For all aluminum pipes, the top of the pipe should be located a minimum of 0.3 feet below the surfacing subgrade.

Notes:

① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.

② For a given fill height, the wall thicknesses for both the 2⅔” x ½” and 3” x 1” corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.

③ Fill heights taken from manufacturers'/suppliers' product information.

11.2.5.5 Steel Casing Pipe (SCP)

Steel casing pipe (SCP) is typically installed by jacking and boring methods. To accommodate jacking pressures and fill heights, thicker pipe walls will be necessary as the pipe diameter increases. Jack-and-bore installations are most commonly used on projects with high fills and/or to avoid impacting the roadway cross section. Exhibit 11-17 provides minimum pipe thicknesses for SCP based upon the pipe diameter. The Contractor will need to determine if this minimum thickness is structurally sufficient for the proposed jacking and/or boring loads, and increase pipe thickness if necessary.

Exhibit 11-17
Minimum Thicknesses for Steel Casing Pipes (SCP)

Steel Casing Pipes (SCP)	
Pipe Diameter (in)	**Minimum Pipe Thickness (in)**
18	0.250
24	0.312
30	0.375
36	0.500
42	0.500
48	0.625
54	0.625
60	0.625
66	0.625
72	0.750

Table is from the following document: DEPARTMENT OF THE ARMY EM 1110-2-2902 U.S. Army Corps of Engineers Change 1 CECW-ED Washington, DC 20314-1000 Manual No. 1110-2-2902 31 March 1998 Engineering and Design CONDUITS, CULVERTS, AND PIPES Table 8-1

11.2.5.6 Plastic Pipes

High-density polyethylene (HDPE) pipe is limited for use underneath private approaches and under mainline roadways on a case-by-case basis. Solid-wall or profile-wall polyvinyl chloride (PVC) pipe may be specified for irrigation and storm drain applications on a case-by-case basis. Exhibit 11-18 presents structural requirements for plastic pipes.

Exhibit 11-18 Structural Requirements for Plastic Pipes

PLASTIC PIPES					
PIPE DIAMETER (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT* (ft)			
		HDPE①	Profile Wall PVC ②	Solid Wall PVC ③ Pipe Stiffness (psi)	
				46	115
12	24	18	24	*24④*	*30④*
18	24	17	24	24	30
24	24	15	24	24	30
30	24	14	23	24	30
36	24	12	22	24	30
42	24	12	-	24	30
48	24	11	-	24	30

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

For all plastic pipes, the top of the pipe should be located a minimum of 0.3 feet below the surfacing subgrade.

Notes:

① HDPE smooth lined or corrugated, Corrugated Polyethylene Drainage Pipe Standard Specification 708.07

② Profile Wall PVC, Standard Specification 708.05.4

③ Large Diameter Solid Wall PVC Gravity Pipe, Standard Specification 708.05.3

④ PSM PVC Solid Wall Gravity Pipe, Standard Specification 708.05.2

(AASHTO M294) *(2)*.

11.2.5.7 Road Approach Pipes

Pipes located underneath public road approaches must be at least 24” in diameter, while pipes located underneath private approaches and farm field approaches must be at least 18” in diameter. See Exhibit 11-19 for acceptable pipe cover ranges for different pipe types underneath private approaches.

Locate the entire road approach pipe, including the end treatments, outside the clear zone where practical. Flared End Treatment Sections (FETS) will be provided for all approach culverts located outside the clear zone. Where it is not practical to place approach culverts outside the clear zone, specify the 6:1 Road Approach Culvert End Treatment Section (RACETS).

Exhibit 11-19 Structural Requirements for Private Approach Pipes

Private Approach Pipes			
Pipe Size & Type	**Class of Pipe**	**Minimum Fill Height* (ft)**	**Maximum Fill Height* (ft)**
18” RCP	2	①	①
	3	1.5	15
	4	0.5	22
	5	0.5	33
18” CSP	--	1	142
18” CAP	--	1.5	75
18” HDPE	--	2	17

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

Notes:

① Class 2 reinforced concrete pipe does not exist for 18” diameter pipe.

11.2.6 Multiple Pipe Installations

It may be necessary to install two or more adjacent culverts at one location to provide adequate conveyance. Multiple pipe installations are identified as a "double" or a "triple" installation at the station representing the center of the installation.

The spacing between outside faces of adjacent pipes normally will be a minimum of 4 feet, but may be increased to a maximum of 8 feet to aid in installation and backfill. If FETS are used, specify at least 2 feet between the outside ends of adjacent terminal sections.

11.2.7 Special Culvert Installations

The potential for settlement at or near larger culverts should be evaluated and addressed during the preconstruction phases. Settlement issues at or near a large culvert could be due to either settlement of the foundation soil below the culvert or where achieving adequate compaction of backfill around the culvert may be problematic (ultimately leading to differential settlement).

If none of these seven conditions/parameters is present, then standard culvert design practices and procedures should be followed.

A special culvert installation is needed if one or more of the following conditions/parameters are present:

1. Large culverts: 10-foot diameter (or equivalent arch pipe) or greater (difficult to obtain compaction below pipe haunches);
2. Low fill heights/cover above the culvert (5 feet or less) measured from top of culvert to top of pavement section;

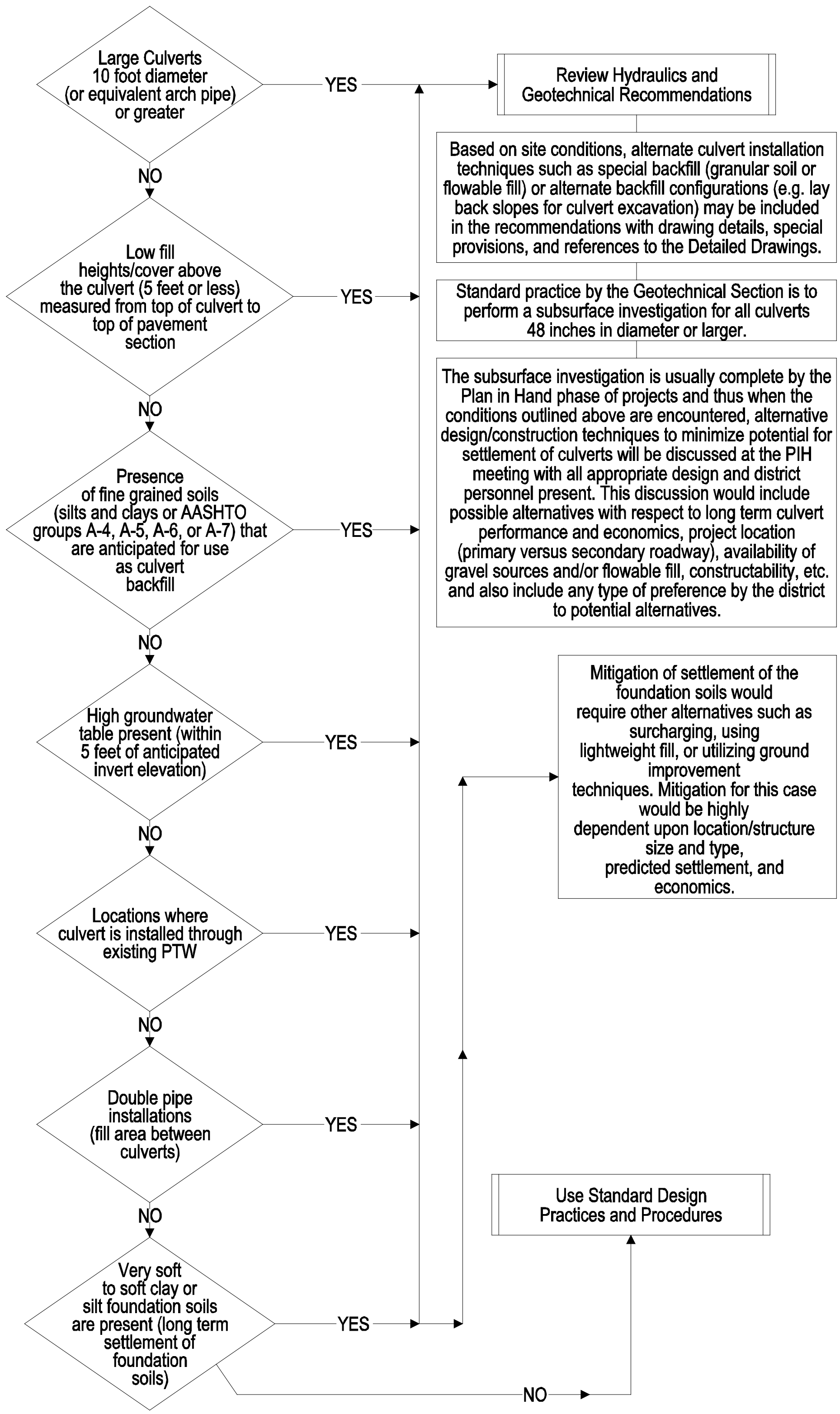
3. Presence of fine-grained soils (silts and clays or AASHTO groups A-4, A-5, A-6, or A-7) that are anticipated for use as culvert backfill;
4. High groundwater table present (within 5 feet of anticipated invert elevation);
5. Locations where culvert is installed through the existing present travel way (PTW). A widened PTW can lead to differential settlement and/or areas where a vertical trench excavation might be used to install culverts;
6. Multiple pipe installations (fill area between culverts); or
7. Very soft to soft clay or silt foundation soils are present (long-term settlement of foundation soils).

If a special culvert installation is needed, then evaluate alternate culvert installation and backfill techniques as follows:

- Review the hydraulics designer's and Geotechnical Section Recommendations.
- Based on site conditions, alternate culvert installation techniques such as special backfill (granular soil or flowable fill) or alternate backfill configurations (e.g., lay backslopes for culvert excavation) may be included in the recommendations along with drawing details, special provisions, and references to the *MDT Detailed Drawings*.
- When No. 7 above is encountered, mitigation of settlement of the foundation soils would require other alternatives such as surcharging, using lightweight fill, or utilizing ground improvement techniques. Mitigation for this case would be highly dependent upon location/structure size and type, predicted settlement, and economics.
- Standard practice by the Geotechnical Section is to perform a subsurface investigation for all culverts 48" in diameter or larger. As part of the subsurface investigation, items No. 3, 4, and 7 should be identified by the Geotechnical Section. The remaining items will be readily known from the proposed project Scope of Work, hydraulic design reports, and plans/cross sections.
- The subsurface investigation is usually complete by the Plan-In-Hand (PIH) phase of projects and thus when the conditions outlined above are encountered, alternative design/construction techniques to minimize potential for settlement of culverts will be discussed at the PIH meeting with all appropriate design and District personnel present. This discussion would include possible alternatives with respect to long term culvert performance and economics, project location (primary versus secondary roadway), availability of gravel sources and/or flowable fill, constructability, etc., and also include any type of preference by the District to potential alternatives.

If none of the above seven conditions/parameters is present, then standard culvert design practices and procedures should be followed. Exhibit 11-20 presents the guidelines described above for determining the need for special culvert installation and presents the coordination items the design team should complete to perform the design of a special culvert installation.

Exhibit 11-20
Special Culvert Installation Guidelines



11.2.8 Culvert End Treatments

Special treatments are typically required for the ends of culvert installations. Exhibit 11-21 provides criteria for determining the proper end treatments for cross drain structures based upon pipe type and size. These end treatment criteria apply to both single- and multiple-pipe installations. Refer to Chapter 9 for detailed information on the proper use and installation of culvert end treatments in relation to roadside safety best practices.

See the *MDT Detailed Drawings* for the standard culvert end treatments.

Exhibit 11-21
Culvert End Treatment Determination

Pipe Type and Size	End Treatment	Cutoff Walls	Inlet/Outlet Concrete Edge Protection
RCP ≤ 48"	FETS	No	No
RCP ≥ 54”	FETS	Yes	No
RCPA ≥ 65" x 40"	FETS	Yes	No
CMP ≤ 48”	FETS	No	No
CMP ≥ 54"	Step Bevel①	Yes	Yes
CSPA or SSPPA ≥ 54"	Bevel①	Yes	Yes
SCP ≤ 48”	FETS	No	No
SCP ≥ 54"	Square	Yes	Yes

CMP = Corrugated Metal Pipe (CSP or CAP)

FETS = Flared End Terminal Section

Notes:

① Type of bevel will be identified on the plans and culvert summary frame (e.g., 2:1 step bevel, 2:1 bevel).

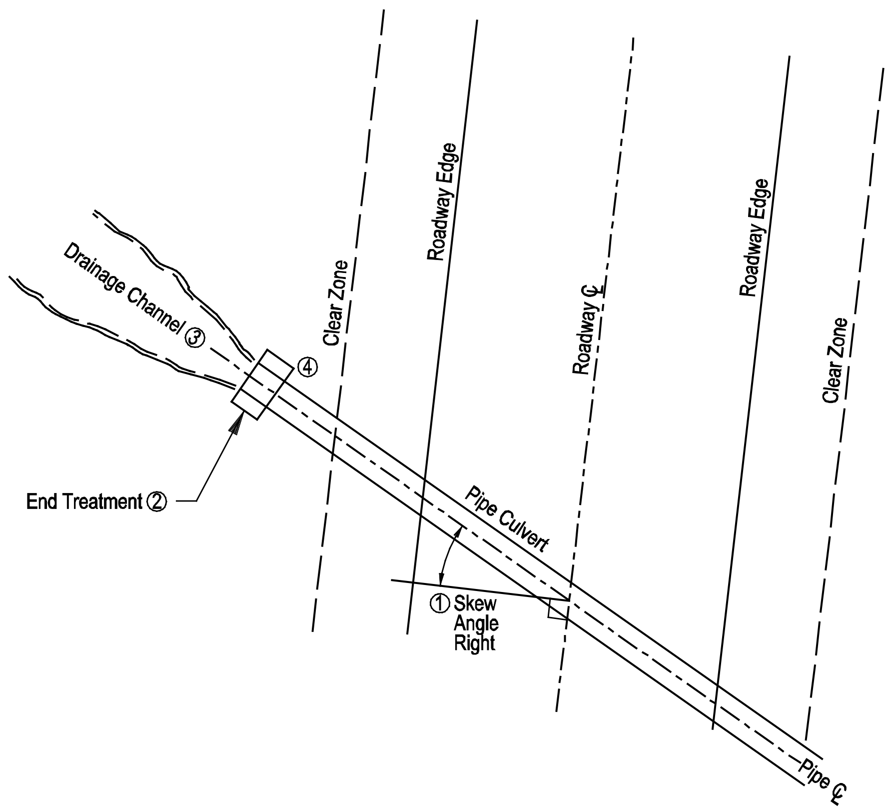
② In special situations, square ends may be specified by the hydraulics designer. For square ends on culverts ≤ 48” or equivalent, the culvert length should be extended 2 feet beyond the toe of the fill slope. For square ends on culverts ≥ 54” or equivalent, add cutoff walls and concrete edge protection to the inlet and outlet.

11.2.8.1 Skewed Pipe Installations

The skew is defined as the angle measured left or right from a line which is perpendicular to the roadway centerline. See Exhibit 11-22 for a general illustration of pipe skew in relation to the roadway orientation.

Concrete pipes shall not be beveled or skew-beveled.

Exhibit 11-22
Pipe Skew



① Pipe skews will typically not exceed 35 degrees. A skew angle right is one where the pipe centerline is to the right of a line extended perpendicular from the roadway centerline. A skew angle left is one where the pipe centerline is to the left of a line extended perpendicular from the roadway centerline.

② The end treatments for all single concrete pipe and corrugated steel pipe installations with diameters 48" or less will be installed perpendicular to the centerline of the pipe regardless of pipe skew, unless specified otherwise by the hydraulics designer.

The following will apply to installations of corrugated steel and structural steel plate pipe diameters 54" or greater:

For skew angles 0° to 15°, the end treatment should be perpendicular to the centerline of the pipe.

For skew angles 16° to 35° and fill height 10 feet or less, the end treatment should generally be skew-beveled. The design team should verify this with the hydraulics designer.

For skew angles 16° to 35° and fill height greater than 10 feet, the end treatment should generally be perpendicular to the centerline of the pipe and the fill warped to the pipe ends. The design team should verify this with the hydraulics designer.

③ Consider channel realignment changes where appropriate, with consideration of potential environmental impacts, to limit pipe skew.

④ The pipe should be extended so that the near corner of the edge protection catches the fill slope beyond the clear zone.

Skewed Installations. Concrete pipes cannot be beveled or skew beveled. The design team should note the following considerations for metal pipe end treatments with skewed installations for pipe diameters of 54″ or greater:

- Multiple-pipe installations will use the same end treatment as single-pipe installations except that, for skews from 16° to 35°, the end treatment will be skew-beveled regardless of fill height.
- Skew-bevel or skew step-bevel end sections are cut parallel to the centerline of the roadway.
- If it is determined necessary to skew-bevel a pipe end, provide concrete edge protection and cutoff walls on both ends.
- The type of bevel and the amount of skew are to be identified in the culvert summary.
- If temporary bracing of skew-beveled pipe ends is required, it must be addressed by special provision.

11.2.8.2 Inlet and Outlet Edge Protection

The hydraulic characteristics of some drainage channels may require special protection for the roadway embankment at the inlets and outlets of pipe installations. The hydraulics designer will provide design information for special features.

If skew-bevels are used, concrete edge protection is required to strengthen the top arch on the pipe inlet and outlet. Bolting should follow the *MDT Detailed Drawings*.

If a culvert requiring edge protection is skewed, the design team should design the edge protection to match the roadway inslope and extend the culvert sufficiently to be adequately protected by the edge treatment.

For metal pipes 48″ or less in diameter, it is not necessary to provide for special protection unless the hydraulics designer provides specific recommendations to do so. For metal pipes 54″ or larger in diameter, provide the protective measures described in the *MDT Detailed Drawings*, as applicable:

- Cutoff walls at both ends, and
- Concrete edge protection at inlet and outlet.

See the *MDT Detailed Drawings* and *MDT Hydraulics Standard Drawings* for estimated quantities for cutoff walls and inlet and outlet edge protection.

Concrete pipes 54″ or larger in diameter with FETS require cutoff walls at both ends. Concrete edge protection should not be used unless specified by the hydraulics designer. Riprap edge protection should not be used in conjunction with the standard end treatment for concrete pipe unless specified by the hydraulics designer.

11.2.9 Pipe Bedding/Foundation

Bedding is required for all pipe installations per the *MDT Detailed Drawings*. For pipes 48″ in diameter or less, bedding is paid for within the cost of the pipe and does not need to be shown in the culvert summary. For pipes 54″ or larger in diameter, granular bedding must be quantified and paid for separately and specified in the culvert summary in accordance with the *MDT Detailed Drawings*.

When foundation material is specified, it will be placed below the granular bedding or bedding material. Foundation material must be quantified and paid for separately and specified in the culvert summary in accordance with the *MDT Detailed Drawings*.

11.2.10 Riprap

The hydraulics designer will typically design embankment protection, outlet aprons, and other features requiring riprap. The hydraulics designer will work with the design team to calculate quantities and provide the necessary details. Show the riprap on the plans and cross sections and include the quantities in the appropriate summary.

The layout and quantities of riprap at bridge ends will be coordinated between the design team, the hydraulics designer, and the Bridge Bureau. Riprap will be shown on both the plan and profile, and the quantities will be included in the appropriate summary. Riprap details may need to be included in the plan set. Geotextile will be provided with all riprap installations unless otherwise specified.

11.2.11 Metal Culvert Extensions

The following will apply for metal culvert extensions:

- The hydraulics designer will evaluate the remaining service life of the pipe to determine if it should be extended or replaced. This determination is generally based on the condition of the in-place pipes.
- The length of extension includes the new end treatment section, unless the existing section will be removed and re-laid. Note this in the culvert summary.
- The design team is responsible for determining the length of pipe extensions. The hydraulics designer may recommend new end treatments on a case-by-case basis.
- If the existing pipe is a metric size, the diameter will be converted to US Customary units and rounded to the nearest inch (e.g., 600mm = 24 inches). The pipe extensions will be called out using the available US Customary size for the pipe.
- The thickness of the extension pipe should match the existing pipe thickness (e.g., a 0.064” thick pipe extension should not be connected to an existing pipe that is 0.079” thick).
- When the material or configuration of the existing pipe cannot be matched, a concrete collar will be needed to connect the extension to the existing pipe. Metal bands can be used to connect CSP to SSPP where the connection is beyond the edge of the surfacing section. This connection will require a special detail, and a CSP Verification special

Re-lay means to reinstall the existing culvert end treatment rather than installing a new end treatment.

provision will typically be included, requiring the contractor to verify the existing CSP pipe dimensions prior to lengthening.
- Fill height for pipe extensions will be measured at the point of connection to the existing pipe unless otherwise specified.

11.2.12 Reinforced Concrete Pipe Extensions

The required minimum length of extension for reinforced concrete pipe is as follows (length is measured from the end of the existing pipe barrel minus the existing end treatment or any damaged pipe sections.):

- Diameter ≤ 30″: 10 feet, including 4 feet of new pipe and a 6-foot standard terminal section.
- 30″ < Diameter ≤ 72″: 12 feet, including 4 feet of new pipe and an 8-foot standard terminal section.
- Diameter > 72″: Contact the hydraulics designer.
- If extension of the barrel is not required, a FETS can be added without any additional length of pipe.
- Fill height for pipe extensions should be measured at the point of connection to the existing pipe.
- Connection to the existing RCP pipe can be made by matching the existing RCP joint, utilizing an RCP Adapter Ring in accordance with the *MDT Detailed Drawings*, or a Field Cast Concrete Connection in accordance with the *MDT Detailed Drawings*.

11.2.13 Culvert Cleaning

It may be desirable to include cleaning of existing culverts with design projects. The following guidelines should be followed to determine and document whether a culvert is eligible for cleaning on projects involving Federal-aid funds:

- Only culverts larger than 48″ are eligible to be cleaned with Federal-aid funds. All culverts larger than 48″ will be evaluated for cleaning on a case-by-case basis. The decision should be based on the size, location, severity of the problem, and whether specialized equipment would be needed.
- Culvert cleaning should not normally be included in preventative maintenance projects.
- A list of smaller culverts (48″ and smaller), not eligible but in need of cleaning, can be sent to the appropriate MDT Maintenance Division to schedule cleaning activities.

These guidelines on culvert cleaning apply only to projects involving Federal-aid funds.

11.2.14 Abandonment of Culverts

If the decision is made to abandon a culvert in place, rather than remove the culvert, three methods are allowed for the abandonment.

Abandon. This should be used when a culvert is either filled with silt or is shown in the as-built plans but cannot be found. It should be noted in the plans, and since it does not require any additional work, no pay item is provided.

Plug Ends and Abandon. This should be used when a culvert is being abandoned but is small enough and in deep enough fill that it does not need to be filled throughout its length. The culvert will be filled for a distance of 10 feet from each end and the culvert ends will need to be capped to prevent material from infiltrating the abandoned culvert. Crushing the ends is an acceptable means of capping culverts.

Use the Plug Ends and Abandon treatment when both of the following criteria exist:

- The culvert diameter is 36” or less, and
- The culvert has at least 15 feet of cover.

Refer to Chapter 13 for information on calculating the quantity of culverts that are to be plugged and abandoned and include a special provision in the plans.

Fill and Abandon. Culverts must be filled and abandoned when they do not meet the criteria for Plug Ends and Abandon. As a general practice, fill and abandon all storm drains that are not removed.

Refer to Chapter 13 for information on calculating the quantity of culverts that are to be filled and abandoned and include a special provision in the plans.

11.3 SPECIAL-PURPOSE LARGE CULVERTS

Coordinate with the Right-of-Way Bureau for stockpass and vehicular underpass requirements.

Large culverts frequently may be used for purposes other than to accommodate drainage. They may serve as stockpasses, wildlife underpasses, vehicular underpasses with surfacing, or pedestrian/bicycle underpasses. The following criteria present guidance for special-purpose large culverts.

11.3.1 Stockpasses

Record stockpass culverts in a separate summary frame. Include associated paving in the additional surfacing frame.

A standard metal pipe may be designed to serve as a stockpass by using the treatment shown in the *MDT Detailed Drawings*. It should be specified only when justified by right-of-way negotiations. The primary purpose of this structure is to serve as a stockpass. However, stockpasses may also act as cross drains. Where possible, stockpasses should be separated from drainages and the stockpass invert elevation should be set to avoid water flow. Adjacent, lower-elevation culverts may also be provided for drainage when necessary. The design team should attempt to minimize the stockpass length whenever practical. A perpendicular crossing is preferred; however, if a skew is necessary, it should not exceed 15°.

The same bedding and fill height requirements for drainage culverts also apply to stockpasses. The design team should adhere to the maximum and minimum fill height requirements in the fill height exhibits.

11.3.2 Wildlife Underpasses

Wildlife underpasses are intended to provide connectivity across highways while reducing collisions between vehicles and animals. The size and structure type will vary in accordance with the size and type of animal species to be accommodated and potentially by the crossing length. When a culvert is used, it is typically sunk and backfilled with natural soil and used in conjunction with wildlife exclusionary fencing. The design team should coordinate with the hydraulics designer as the culvert will often function as both a wildlife crossing and a drainage culvert.

The location and size of the culvert should be coordinated with the Environmental Resources Section.

11.3.3 Vehicular Underpasses

Specify a circular structural steel plate pipe vehicular underpass unless directed otherwise by the Hydraulics or Geotechnical Sections. Construction personnel and the design team should review the installation for special construction requirements when staged construction is specified. Granular bedding material should be specified for all large culverts.

The *MDT Detailed Drawings* show the backfill retainer and cutoff wall requirements as well as the floor surfacing criteria for the underpass. The concrete collar shown in the *MDT Detailed Drawings* will be provided for vehicular underpasses.

The design team should adhere to the maximum and minimum fill height requirements in the fill height exhibits.

11.3.4 Pedestrian/Bicycle Underpasses

Pedestrian and bicycle underpasses are typically designed using a 10′ x 10′ equivalent opening. These structures may include lighting, special grouting, or paving to meet ADA guidelines. All pedestrian and bicycle underpasses should be ADA-compliant up to and through the underpass from both directions. A curb to direct drainage/snowmelt around the top of the pipe should be considered.

11.4 STORM DRAINS

The detailed design of storm drains will be prepared by the hydraulics designer. The design will include the size, type, and location of the trunk line, manholes, lateral lines, and drop inlets. Refer to the *MDT Detailed Drawings* for storm drain trench and bedding details.

The design team will coordinate with the hydraulics designer to establish the locations and finished grade elevations at manholes and drop inlets, ensure that the trunk line and laterals have adequate cover, and identify conflicts with in-place utilities. The hydraulics designer will coordinate with the Utilities Section regarding utilities crossing the proposed storm drain. A SUE2 survey may be required to identify and avoid utility conflicts.

A SUE2 survey involves identifying and locating underground utilities via evacuation of material to determine and record the utility depths and invert elevations.

11.4.1 Storm Drain Inlets

The hydraulics designer will recommend the types and locations of storm drain inlets. Details for storm drain inlets are provided in the *MDT Detailed Drawings*. The roadway designer will verify the inlet locations are located at low points of sag curves and will also check the inlet locations for conflicts with curb ramps, in-place utilities, approaches, or other features. This is an iterative process and will require coordination with the Hydraulics and Utilities Sections.

11.4.2 Manholes

The size and location of manholes will be specified by the hydraulics designer. The roadway designer will check the locations for conflicts with in-place utilities. Existing manholes can be adjusted up to a maximum of one foot through the use of adjusting rings to match new grades. All manholes requiring adjustment should be identified on the plans with notes added identifying specific items required by owners (e.g., concrete collars). Manholes that have been previously adjusted, need to be lowered, or requiring adjustments greater than one foot will require additional investigation and may result in substantial modification or replacement.

11.4.3 Curb Bulb-Outs

Where curb bulb-outs are used on urban routes with curb and gutter sections, the design team should check bulb-out locations and gutter grades to determine if the bulb-outs will block the gutter flow or interfere with storm drain inlets. The hydraulics designer will determine if existing storm drain inlets should be relocated or if new inlets or other drainage features are required to maintain roadway drainage.

11.5 ROADSIDE DRAINAGE

Effective roadside drainage is one of the most critical elements in the design of a roadway. Drainage features should be designed and constructed considering the potential consequences of run-off-the-road vehicles. See Chapter 9, Section 9.3.5 for additional safety considerations and information on roadside drainage features.

Additional information on maintenance of Existing Drainage Features can be found in the *MDT PESC Design Guidelines*.

The design team should also strive to minimize interference with existing roadside drainage patterns to the extent possible. Care should be taken to maintain existing drainage patterns throughout the project and to tie into existing ditches at the project ends. If the redirection of existing flows is unavoidable, this should be discussed with the hydraulics designer, and careful attention and consideration should be given to the impacts the redirection may have on adjacent properties, flooding, and erosion.

Drainage in the roadside ditch sometimes is made complicated by landowners who use the roadside ditch to carry irrigation wastewater. Although MDT prefers to have separate irrigation wastewater ditches constructed outside of the roadway right-of-way, perpetuation of irrigation wastewater in the roadside ditch should be evaluated on a case-by-case basis. Whenever the roadside ditch is used for any irrigation purpose, the design team should coordinate with the hydraulics designer.

11.5.1 Cut Sections

Roadside ditches generally use a 10-foot, 20:1-bottom configuration, and the grade of roadside ditches typically matches the profile grade of the roadway. However, more detailed ditch design needs to be considered for the following situations:

- Ditches on sustained grades may carry relatively high volumes of runoff that can result in erosion to the ditch and the cut-to-fill transition. When sustained grades are encountered, the design team needs to consider the use of erosion control features discussed in the *MDT PESC Design Guidelines.*
- Extremely flat ditches also need additional design. Separate ditch grades need to be considered for 50 feet on each side of the crest if the grades along the curve are 0.30-percent or less. Separate ditch grades may also be necessary along a superelevated section where the profile grade is 0.5-percent or less.

11.5.2 Fill Sections

Drainage considerations in fill sections generally involve the following features:

- The location of minimum size (24”) culverts is often overlooked. The design team should review as-built plans to determine the location of existing culverts. When a project involves modification to the existing vertical alignment, the design team must also review the new profile grade to ensure that cross drains are provided in low spots where water would otherwise be trapped.
- Many older sections of roadway were constructed using side borrow, which resulted in substantial roadside ditches adjacent to the roadway embankment. New, wider roadway templates often fill these ditches, leaving no clear drainage path and often pushing runoff onto adjacent landowners. The design team should review these areas to ensure drainage is conveyed at the toe of the slopes. Additional ditch grading or cross drains may alleviate the problem. Construction of a drainage ditch at the toe of fill may be needed to convey runoff to a natural drainage.

Design teams also need to conduct on-site reviews (Alignment and Grade, Plan-In-Hand) to determine the location of minor natural drainages.

11.6 MISCELLANEOUS DRAINAGE FACILITIES

11.6.1 Embankment Protectors

Embankment protectors, as shown in the *MDT Detailed Drawings*, should be installed at the corners of bridges and on high fills to control runoff unless their elimination can be justified (e.g., corners on the high side of a superelevated cross section). When the installation of embankment protectors is impractical (e.g., an embankment protector pipe would be located where it may become plugged with sediment, debris, or ice), the use of drain chutes may be considered. Do not install embankment protectors for bridges having rail configurations without curb (e.g., T101 rail). Typical installations for bridges are described as follows:

1. Four-lane divided roadway on tangent:
    a. Embankment protectors at the four outside corners.
    b. Concrete curb at the four inside (median side) corners.
    c. Median drains with median inlet and cross drain, or an outlet between structures with embankment protection. Ditch blocks should be installed at the median inlet, and concrete curbs should be installed from the bridge ends to intercept drainage and prevent it from eroding the material at the ends of the structure wingwalls.
2. Four-lane divided roadway on curve:
    a. Embankment protectors on the two outside corners on the low side of the curve.
    b. Concrete curb at the two inside (median side) corners on the low side of the curve.
    c. Median inlets same as on tangent section.
3. Two-lane or four-lane with narrow median:
    a. On tangent: embankment protectors at the four corners.
    b. On curve: embankment protectors at the two corners on the low side of the curve.

Where drainage flows toward the structure, place embankment protectors as near to the structure as practical. On long, continuous sections of high fill, locate embankment protectors based on spread width calculated by the hydraulics designer.

11.6.2 Drainage Chutes

The drainage chutes described in the *MDT Detailed Drawings* may be used for backslope protection where the backslope intercepts a natural drainage coulee or where embankment protectors are not practical.

11.6.3 Median Inlets

Three types of median inlets are available. Each type is shown in the *MDT Detailed Drawings.* The hydraulics designer will determine the type of inlet and spacing to be used. Specify the type clearly on the plans. Tables on the applicable *MDT Detailed Drawings* present estimated quantities of materials.

11.6.4 Underdrains

The Geotechnical Section should be consulted for all subsurface recommendations. Unusual subsurface water conditions frequently are encountered during field locations and soils surveys. Some form of underdrain will be recommended by the Geotechnical Section to alleviate such conditions.

For each underdrain, the details should clearly define the location, the type, the depth of placement, and the drain aggregate and geotextile to be installed with the pipe. Outlet designs and cleanouts should also be included. On urban projects with new or existing storm drains, it can be evaluated on a case-by-case basis whether the underdrains may outlet directly into drop inlets.

11.6.5 Sidewalk Drains

Sidewalk drains may be required to drain low areas behind the sidewalk or to perpetuate drainage across sidewalks from rain gutter down pipes. Sidewalk drains may also be used to perpetuate drainage through sidewalk bulb-outs.

11.6.6 Other Facilities

Coordination with the hydraulics designer may be required for special designs such as ditch blocks, interceptor ditches, streambank protection, and detention and retention basin design. The design team will review locations and ensure that the design details are included in the plans.

11.7 IRRIGATION FACILITIES

11.7.1 Irrigation Pipe

Irrigation facilities will require water-tight pipe. In the culvert summary and the culvert summary recap, record these pipes separately and identify them as "Irrigation" or "Siphon." The hydraulics designer will provide flowline and pipe invert elevations for all irrigation installations. These elevations are critical to effective operation of the irrigation system. Irrigation pipe material will be selected by the hydraulics designer.

11.7.2 Irrigation Siphon Pipe

Some irrigation pipes will be "siphons," where the pipes are angled down under the roadway ditches with the inlet and outlet elevations higher than the pipe under the roadway centerline. The hydraulics designer will design siphons and provide the Siphon Detail Sheet.

11.7.3 Division Boxes

The hydraulics designer will provide the design and details for concrete division boxes. Some types of division boxes are shown in the *MDT Detailed Drawings*.

11.7.4 Irrigation Ditch Relocations

The hydraulics designer will provide recommendations for ditch relocations and linings, if required. Relocate longitudinal irrigation ditches outside of the right-of-way line where feasible. To avoid irrigation ditch maintenance within the roadway right-of-way, irrigation pipes 30″ in diameter and less should be extended 24″ beyond the right-of-way line where practical. The right-of-way fence may be winged into the pipe ends for irrigation pipes larger than 30″ in diameter to minimize the cost of pipe extension.

11.7.5 Inlet and Outlet Headwalls

The hydraulics designer will provide recommendations and design details for concrete headwalls. Some headwall details are included in the *MDT Detailed Drawings*.

11.8 ENCASEMENT PIPES

This section is intended to provide general guidelines for material selection when specifying an encasement pipe for proposed pressure irrigation lines, sanitary sewers, and water lines. The request for an encasement pipe generally comes in the form of a landowner request or possibly from a municipality for a future water or sanitary sewer line. Encasement pipes may be required for the following reasons:

- Prevent damage to structures caused by soil erosion or settlement in case of pipe failure or leakage.
- Allows economical pipe removal and replacement in the future.
- Accommodate regulations or requirements imposed by public or private owners of property in which the pipe is installed.
- Allows boring rather than excavation where open excavation would be impossible or prohibitively expensive.

In general, MDT prefers to provide uncased pipeline crossings through the roadway. In these circumstances, the following materials can be considered for pipeline crossings:

- PVC Pressure Water Pipe
- Ductile Iron Water Pipe
- Steel Water Pipe

When installation of an encasement pipe is warranted, the following encasement pipe materials may be considered. See the *MDT Hydraulics Manual* for specific encasement pipe application guidelines for each material.

- Corrugated Steel Pipe (CSP)
- PVC Gravity Sewer and Drain Pipe (SDR 35)
- High Density Polyethylene (HDPE) - *Subject to review and approval of the hydraulics designer*
- Steel Casing Pipe (SCP)
- Reinforced Concrete Pipe (RCP)

11.9 REFERENCES

1. American Association of State Highway and Transportation Officials (AASHTO). *Model Drainage Manual.* AASHTO, Washington, D.C., 2014.
2. AASHTO. *Standard Specifications for Transportation Materials and Methods of Sampling and Testing.* AASHTO, Washington, D.C., 2013.