8.0 STRUCTURAL ASPECTS OF CULVERTS

The structural design of a culvert can affect its hydraulic performance and service life and the structural integrity of the highway embankment. This section presents structural design criteria and procedures for reinforced concrete pipe (RCP), corrugated metal pipe (CMP), spiral rib steel pipe (SRSP), corrugated metal, metal arch culverts (CMMAC), corrugated aluminum pipe (CAP), corrugated aluminum pipe arch (CAPA), thermoplastic pipes including polyvinyl chloride pipe (PVCP) and polyethylene pipe (PEP), and reinforced concrete box culverts (RCB) installed in embankments. This section does not cover the design of reinforced concrete elliptical and arch pipe, or other types of pipe. It also does not cover trench installations. References listed in Section 8.5 provide technical guidance on structural design for other types of pipe and other methods of installation.

Pipe culverts may be added or replaced in existing embankments by tunneling, jacking or boring. This section does not include structural criteria for tunneling, jacking or boring because these types of installations are typically done in accordance with standards set by the industry or by other governmental agencies. A special provision is required for pipe culvert installation by tunneling, jacking or boring.

The structural adequacy of a pipe or RCB culvert may need to be considered at locations with low type surfacing and minimum cover over the top of the culvert. Culverts at these locations, such as a field entrance for agricultural purposes, may be subjected to heavy loads from large trucks and/or agricultural equipment.

8.1 PIPE INSTALLATION

8.1.1 General Procedure

The following general procedure should be used to install pipe culverts:

1. The channel or trench is graded to the appropriate elevation.
2. A pipe bed or template is formed by shaping the bottom of the channel or by placing granular material, depending on the size of the pipe.
3. The pipe is placed in the bed.
4. The channel or trench is backfilled.

Detailed information on excavation and backfill for culverts is presented in Section 204 of KDOT's *Standard Specifications for State Road and Bridge Construction*.

8.1.2 Minimum Spacing

A minimum spacing between pipes in multiple-barrel culverts is needed to permit adequate compaction of the backfill material and to provide clearance for the end sections. Standard Drawing RD668 "Miscellaneous Pipe Culvert Details" includes information to determine minimum spacing between pipes. A width to accommodate end sections should be considered.

8.1.3 Pipe Lengths

For constant gradient pipe culverts and erosion pipe compute and tabulate the length in multiples of 2' for concrete pipe and to the nearest 1' for metal pipe. When multiple pipe types are acceptable for use at a site, round the length to the nearest 2'. For additional information regarding pipe lengths, see the Road Design Manual.

8.2 REINFORCED CONCRETE PIPE

Use Table 8.2-1 to determine the maximum height of fill for RCP installed in embankments. These maximum heights of fill are based on the AASHTO LRFD Indirect Design Method (D-Load Method) and the following design criteria:

Positive projecting embankment installation

Unit weight of the fill = 120 lb/ft^3

Type 3 Installation Type

Settlement ratio r_{sd} = 0.7

D-loads for 0.01-in. crack: D_{001} = 1000 lb/ft/in. for Class II RCP

$D_{0.01}$ = 1350 lb/ft/in. for Class III RCP

$D_{0.01}$ = 2000 lb/ft/in. for Class IV RCP

$D_{0.01}$ = 3000 lb/ft/in. for Class V RCP

The minimum cover for RCP and reinforced concrete horizontal elliptical pipe (RCPHE) in unpaved areas and under flexible pavements is 12 in. or one-eighth of the diameter or span, whichever is greater. Under rigid pavements, the minimum cover from the top of the pipe to the top of the subgrade is 9 in. RCPHE is intended for use where the cover over the pipe is limited. RCPHE should be used only where the available cover is insufficient for RCP.

Note: Height of fill tables for RCPHE are not included in this manual.

Table 8.2-1 Design Data for RCP

Pipe Diameter (in.)	Wall Thickness (in.)	Maximum Height of Fill (ft)			
		Class II	Class III	Class IV	Class V
12	2.00	10	14	21	33
15	2.25	10	14	22	33
18	2.50	10	14	22	33
21	2.75	10	14	22	33
24	3.00	10	14	22	33
27	3.25	10	14	21	33
30	3.50	10	14	21	33
33	3.75	9	14	21	32
36	4.00	9	13	21	32
42	4.50	9	13	21	32
48	5.00	9	13	21	32
54	5.50	9	13	20	32
60	6.00	9	13	20	31
66	6.50	8	12	20	31
72	7.00	8	12	20	31
78	7.50	8	12	20	31
84	8.00	8	12	19	31
90	8.50	8	12	19	31
96	9.00	8	12	19	30
102	9.50	8	12	19	30
108	10.00	8	12	19	30

Notes: Pipe diameter is inside diameter.

8.3 CORRUGATED METAL PIPE

Use Tables 8.3-4 through 8.3-18 to determine the required pipe gauge, maximum height of fill and minimum cover for CSP, ACSP, SRSP, and CMMAC. The minimum cover is measured from the top of the pipe to the top of the subgrade. The maximum heights of fill are based on the Load and Resistance Factor Design (LRFD) procedure. For the LRFD Service Load condition, the five percent deflection criteria remains the same as the design procedure of Wolf and Townsend (1970). The maximum heights of fill and metal thicknesses in these tables satisfy design criteria for deflection of the pipe, buckling of the pipe wall, and handling and installation strength. Height of fill tables have been provided for the sizes and types of steel pipe most commonly specified and furnished for KDOT projects. For further information, the designer should refer to Section 12 of the “AASHTO LRFD Bridge Design Specifications, 4th Edition”, to determine maximum height of fill for pipe types and/or other installation methods not shown.

Following are the specific design criteria and material properties used to compute the maximum heights of fill in Tables 8.3-4 through 8.3-18.

Positive projecting embankment installation

Unit weight of fill, w = 120 lb/ft^3

Modulus of soil reaction, E': 400 psi, 750 psi or 1500 psi

Deflection lag factor, D_L: 1.75 for E' = 400 psi
1.48 for E' = 750 psi
1.25 for E' = 1500 psi

Soil stiffness coefficient, k: 0.66 for E' = 400 psi
0.42 for E' = 750 psi
0.22 for E' = 1500 psi

Maximum height of fill not to exceed 50 ft

Minimum metal thickness = 0.079 in. (14 gauge)

Maximum deflection = 5% of nominal diameter

Modulus of elasticity of steel, E = 29 x 10^6 psi

Tensile strength of steel, f_u = 45,000 psi

Table 8.3-1 Properties of CMP, and CMMAC

Corrugation	Gauge	A_s (in.^{2}/ft)	I (in.^{4}/in.)	r (in.)
2-2/3 x 1/2 in.	14	0.968	0.00239	0.1721
	12	1.356	0.00343	0.1741
	10	1.744	0.00453	0.1766
	8	2.133	0.00573	0.1795
3 x 1 in.	14	1.113	0.01088	0.3427
	12	1.560	0.01546	0.3448
	10	2.008	0.02018	0.3472
	8	2.458	0.02509	0.3499
5 x 1 in.	14	0.992	0.01109	0.3663
	12	1.390	0.01565	0.3677
	10	1.788	0.02032	0.3693
	8	2.186	0.02509	0.3711

Table 8.3-2 Properties of SRSP

Corrugation	Gauge	A_s (in.^{2}/ft)	I (in.^{4}/in.)	r (in.)
3/4 x 3/4 x 7-1/2 in.	16	0.509	0.0028	0.258
	14	0.712	0.0037	0.250
	12	1.184	0.0055	0.237
	10	1.717	0.0074	0.228

The maximum height of fill for a deflection of 5% is

$$H_{max} = 7.2\left(\frac{EI + 0.061R^3E'}{D_L KwR^3}\right) \qquad (8\text{-}1)$$

where: H_{max} = maximum height of fill above top of pipe (ft)

E = modulus of elasticity of pipe material (psi)

I = moment of inertia of pipe wall (in.^{4}/in.)

R = nominal radius of pipe (in.)

E' = modulus of soil reaction (psi)

D_L = deflection lag factor

K = bedding constant, 0.1

w = unit weight of fill (lb/ft^3)

The maximum height of fill for buckling of the pipe wall and flexibility factor may be determined from information in the AASHTO LRFD Bridge Design Specifications; 4th Edition, Section 12.

The minimum cover for CMP, and CMMAC, is 12 in. or one-eighth of the diameter or span, whichever is greater. The minimum cover for SRSP is 12 in. or one-fourth of the diameter or span, whichever is greater.

Pipe arches are intended for use where the cover over the pipe is limited. CMMAC should be used only where the available cover is insufficient for CMP.

While special bedding, vertical elongation and other practices can increase the maximum height of fill, these practices are usually not economical for highway construction. Use of these techniques should be justified by a comparison of costs.

The value of the modulus of soil reaction, E', will be recommended by the Geotechnical Section of the Bureau of Structures and Geotechnical Services, and may be found in the Soils Report or the Geotechnical Recommendations. If a value of E' is not provided, it can be estimated from Table 8-3-3. The Geotechnical Section should be consulted for assistance.

Table 8.3-3 Guidance for Estimation of the Modulus of Soil Reaction, E'

Soil type for pipe bedding material (Unified Classification System)	E' (psi) for Specified Compaction of Bedding			
	Dumped	Slight[a]	Moderate[b]	High[c]
Fine-grained soils (LL > 50)[d] with medium to high plasticity (CH, MH, CH-MH)	No data available; consult a soils engineer or use E' = 0			
Fine-grained soils (LL < 50) with medium to no plasticity and less than 25% course-grained particles (CL, ML, ML-CL)	50	200	400	1000
Fine-grained soils (LL < 50) with medium to no plasticity and more than 25% course-grained particles (CL, ML, ML-CL) Course-grained soils with more than 12% fines (GM, GC, SM, SC)	100	400	1000	2000
Course-grained soils with less than 12% fines (GW, GP, SW, SP)	200	1000	2000	3000
Crushed rock	1000	3000	3000	3000

[a]Slight compaction = <85% Proctor, <40% relative density

[b]Moderate compaction = 85%-95% Proctor, 40%-70% relative density

[c]High compaction = >95% Proctor, >70% relative density

[d]LL = liquid limits

In certain situations, such as where existing soils have high plasticity, compacted granular backfill may be required to provide an adequate soil envelope around the pipe. In these situations the Soils Report will recommend granular material for backfill. Locations where compacted granular backfill is required should be noted on the plans.

Table 8.3-4 Design Data for CMP with 2-2/3 x 1/2 in. Corrugations, E' = 400 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft)			
		Pipe Gauge			
		14 Gauge	12 Gauge	10 Gauge	8 Gauge
12	12	50			
15	12	50			
18	12	41			
21	12	29			
24	12	22	28		
30	12	15	18		
36	12	12	14	16	
42	12	11	12	13	15
48	12	10	11	12	12
54	12	10	10	11	11
60	12		10	10	10
66	12			10	10
72	12			9	10
78	12				9
84	12				8

Table 8.3-5 Design Data for CMP with 2-2/3 x 1/2 in. Corrugations, E' = 750 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft)			
		Pipe Gauge			
		14 Gauge	12 Gauge	10 Gauge	8 Gauge
12	12	50			
15	12	50			
18	12	50			
21	12	43			
24	12	35	42		
30	12	27	30		
36	12	23	25	28	
42	12	22	23	24	26
48	12	21	21	22	23
54	12	20	21	21	22
60	12		20	21	21
66	12			20	20
72	12			20	20
78	12				20
84	12				19

Table 8.3-6 Design Data for CMP with 2-2/3 x 1/2 in. Corrugations, E' = 1500 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft)			
		Pipe Gauge			
		14 Gauge	12 Gauge	10 Gauge	8 Gauge
12	12	50			
15	12	50			
18	12	50			
21	12	50			
24	12	50	50		
30	12	50	50		
36	12	50	50	50	
42	12	48	49	50	50
48	12	46	47	48	50
54	12	46	46	47	48
60	12		46	46	47
66	12			46	46
72	12			45	46
78	12				45
84	12				45

Table 8.3-7 Design Data for CMP with 3 x 1 in. Corrugations, E' = 400 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft)				
		Pipe Gauge				
		*16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
48	12	15	16	19	23	26
54	12	13	14	16	19	21
60	12	12	12	14	16	18
66	12	11	11	13	14	15
72	12	10	11	12	13	14
78	12		10	11	12	13
84	12		10	10	11	12
90	12		10	10	11	11
96	12		9	10	10	11
102	18			10	10	10
108	18			9	10	10
114	18			9	9	10
120	18				9	10

* ACSP Only

Table 8.3-8 Design Data for CMP with 3 x 1 in. Corrugations, E' = 750 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft)				
		Pipe Gauge				
		*16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
48	12	26	28	32	36	40
54	12	24	25	28	31	34
60	12	22	23	25	27	29
66	12	21	22	24	25	27
72	12	21	21	22	24	25
78	12		21	22	23	24
84	12		20	21	22	23
90	12		20	21	21	22
96	12		20	20	21	21
102	18			20	20	21
108	18			20	20	20
114	18			20	20	20
120	18				20	20

* ACSP Only

Table 8.3-9 Design Data for CMP with 3 x 1 in. Corrugations, E' = 1500 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft) Pipe Gauge				
		*16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
48	12	50	50	50	50	50
54	12	50	50	50	50	50
60	12	48	50	50	50	50
66	12	43	48	50	50	50
72	12	40	47	49	50	50
78	12		46	48	49	50
84	12		43	47	48	49
90	12		40	46	47	48
96	12		37	46	46	47
102	18			46	46	47
108	18			45	46	46
114	18			44	45	46
120	18				45	46

* ACSP Only

Table 8.3-10 Design Data for CMP with 5 x 1 in. Corrugations, E' = 400 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft)				
		Pipe Gauge				
		*16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
48	12	15	16	20	23	26
54	12	13	14	16	19	21
60	12	12	12	14	16	18
66	12	11	11	13	14	15
72	12	10	11	12	13	14
78	12		10	11	12	13
84	12		10	10	11	12
90	12		10	10	11	11
96	12			10	10	11
102	18			10	10	10
108	18			9	10	10
114	18			9	9	10
120	18				9	10

* ACSP Only

Table 8.3-11 Design Data for CMP with 5 x 1 in. Corrugations, E' = 750 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft)				
		Pipe Gauge				
		*16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
48	12	26	28	32	36	40
54	12	24	25	28	31	34
60	12	22	23	25	27	29
66	12	21	22	24	25	27
72	12	21	21	22	24	25
78	12		21	22	23	24
84	12		20	21	22	23
90	12		20	21	21	22
96	12			20	21	21
102	18			20	20	21
108	18			20	20	20
114	18			20	20	20
120	18				20	20

* ACSP Only

Table 8.3-12 Design Data for CMP with 5 x 1 in. Corrugations, E' = 1500 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft)				
		Pipe Gauge				
		*16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
48	12	50	50	50	50	50
54	12	47	50	50	50	50
60	12	43	50	50	50	50
66	12	39	48	50	50	50
72	12	36	44	49	50	50
78	12		41	48	49	50
84	12		38	47	48	49
90	12		36	46	47	48
96	12			46	46	47
102	18			44	46	47
108	18			41	46	46
114	18			39	45	46
120	18				45	46

* ACSP Only

Table 8.3-13 Design Data for SRSP with 3/4 x 3/4 x 7-1/2 in. Corrugations, E' = 400 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft)			
		Pipe Gauge			
		*16 Gauge	14 Gauge	12 Gauge	10 Gauge
24	12	25	30	40	
30	12	17	19	25	
36	12	13	15	18	
42	12	11	12	14	
48	12	10	11	12	14
54	15		10	11	12
60	15		10	10	11
66	18			10	10
72	18			10	10
78	21			9	10
84	21				9
90	24				9

* Aluminized SRSP only

Note: Based on embankment Installation

Table 8.3-14 Design Data for SRSP with 3/4 x 3/4 x 7-1/2 in. Corrugations, E' = 750 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft)			
		Pipe Gauge			
		*16 Gauge	14 Gauge	12 Gauge	10 Gauge
24	12	38	44	50	
30	12	28	31	38	
36	12	24	26	30	
42	12	22	23	26	
48	12	21	22	23	25
54	15		21	22	23
60	15		20	21	22
66	18			20	21
72	18			20	20
78	21			20	20
84	21				20
90	24				20

* Aluminized SRSP only

Note: Based on embankment installation

Table 8.3-15 Design Data for SRSP with 3/4 x 3/4 x 7-1/2 in. Corrugations, E' = 1500 psi

Diameter (in.)	Minimum Cover (in.)	Maximum Height of Fill (ft)			
		Pipe Gauge			
		*16 Gauge	14 Gauge	12 Gauge	10 Gauge
24	12	50	50	50	
30	12	50	50	50	
36	12	46	50	50	
42	12	39	49	50	
48	12	34	48	49	50
54	15		43	48	49
60	15		38	47	48
66	18			46	47
72	18			46	46
78	21			45	46
84	21				45
90	24				45

* Aluminized SRSP only

Note: Based on embankment installation

Table 8.3-16 Design Data for CMMAC with 2-2/3 x 1/2 in. Corrugations

Span x Rise (in.)	MinimumGauge	Minimum Cover (in.)	Maximum Height of Fill* (ft)
17 x 13	14	12	13
21 x 15	14	12	12
24 x 18	14	12	13
28 x 20	14	12	12
35 x 24	14	12	12
42 x 29	14	12	12
49 x 33	14	12	12
57 x 38	12	12	12
64 x 43	12	12	12
71 x 47	10	12	12
77 x 52	8	12	12
83 x 57	8	12	12

*For soil bearing capacity of 2 tons/ft^2 around corners of pipe

Table 8.3-17 Design Data for CMMAC with 3 x 1 in. Corrugations

Span x Rise (in.)	MinimumGauge	Minimum Cover (in.)	Maximum Height of Fill* (ft)
53 x 41	14	12	21
60 x 46	14	15	20
66 x 51	14	15	20
73 x 55	14	18	20
81 x 59	14	18	17
87 x 63	14	18	16
95 x 67	14	18	16
103 x 71	12	18	16
112 x 75	12	21	16
117 x 79	12	21	16
128 x 83	10	24	16
137 x 87	10	24	16
142 x 91	8	27	16

*For soil bearing capacity of 2 tons/ft^2 around corners of pipe

Table 8.3-18 Design Data for CMMAC with 5 x 1 in. Corrugations

Span x Rise (in.)	MinimumGauge	Minimum Cover (in.)	Maximum Height of Fill* (ft)
81 x 59	12	18	17
87 x 63	12	18	16
95 x 67	12	18	16
103 x 71	12	18	16
112 x 75	12	21	16
117 x 79	12	21	16
128 x 83	10	24	16
137 x 87	10	24	16
142 x 91	8	27	16

*For soil bearing capacity of 2 tons/ft^2 around corners of pipe

8.4 CORRUGATED ALUMINUM PIPE

Use Tables 8.4-3 through 8.4-10 to determine the required pipe gauge, maximum height of fill and minimum cover for corrugated aluminum pipe (CAP) and Corrugated Aluminum Pipe Arch (CAPA). The minimum cover is measured from the top of the pipe to the top of the subgrade. The maximum heights of fill are based on the Load and Resistance Factor Design (LRFD) procedure. For the LRFD Service Load condition, the five percent deflection criteria remains the same as the design procedure of Wolf and Townsend (1970). The maximum heights of fill and metal thicknesses in these tables satisfy design criteria for deflection of the pipe, buckling of the pipe wall, and handling and installation strength. Height of fill tables have been provided for the sizes and types of aluminum pipe most commonly specified and furnished for KDOT projects. For further information the designer should refer to Section 12 of the “AASHTO LRFD Bridge Design Specifications, 4th Edition”, to determine maximum height of fill for pipe types and/or other installation methods not shown.

Following are the specific design criteria and material properties used to compute the maximum heights of fill in Tables 8.4-3 through 8.4-10.

Positive projecting embankment installation

Unit weight of fill, w = 120 lb/ft^3

Modulus of soil reaction, E': 400 psi, 750 psi or 1500 psi

Deflection lag factor, D_L: 1.75 for E' = 400 psi
1.48 for E' = 750 psi
1.25 for E' = 1500 psi

Soil stiffness coefficient, k: 0.66 for E' = 400 psi
0.42 for E' = 750 psi
0.22 for E' = 1500 psi

Maximum height of fill not to exceed 50 ft

Minimum metal thickness = 0.060 in. (16 gauge)

Maximum deflection = 5% of nominal diameter

Modulus of elasticity of aluminum, E = 10 x 10^6 psi

Tensile strength of aluminum, fu = 27,000 psi

CAP and CAPA: Helical lockseam or continuously welded seams

Table 8.4-1 Properties of CAP

Corrugation	Gauge	A_s (in.^{2}/ft)	I (in.^{4}/in.)	r (in.)
2-2/3 x 1/2 in.	16	0.775	0.001892	0.1712
	14	0.968	0.002392	0.1721
	12	1.356	0.003425	0.1741
	10	1.745	0.004533	0.1766
	8	2.133	0.005725	0.1795
3 x 1 in.	16	0.89	0.008659	0.3417
	14	1.118	0.010883	0.3427
	12	1.560	0.015459	0.3448
	10	2.008	0.020183	0.3472
	8	2.458	0.025091	0.3499

The maximum height of fill for a deflection of 5% is

$$H_{max} = 7.2\left(\frac{EI + 0.061R^3E'}{D_L KwR^3}\right) \qquad (8\text{-}1)$$

where: H_{max} = maximum height of fill above top of pipe (ft)

E = modulus of elasticity of pipe material (psi)

I = moment of inertia of pipe wall (in.^{4}/in.)

R = nominal radius of pipe (in.)

E' = modulus of soil reaction (psi)

D_L = deflection lag factor

K = bedding constant, 0.1

w = unit weight of fill (lb/ft^3)

The maximum height of fill for buckling of the pipe wall and flexibility factor may be determined from information in the "AASHTO LRFD Bridge Design Specifications, 4th Edition", Section 12.

The minimum cover for CAP and CAPA is as shown on the height of fill tables.

While special bedding, vertical elongation and other practices can increase the maximum height of fill, these practices are usually not economical for highway construction. Use of these techniques should be justified by a comparison of costs.

The value of the modulus of soil reaction, E', will be recommended by the Geotechnical Section of the Bureau of Structures and Geotechnical Services, and may be found in the Soils Report or the Geotechnical Recommendations. If a value of E' is not provided, it can be estimated from Table 8.4-2. The Geotechnical Section should be consulted for assistance.

Table 8.4-2 Guidance for Estimation of the Modulus of Soil Reaction, E'

Soil type for pipe bedding material (Unified Classification System)	E' (psi) for Specified Compaction of Bedding			
	Dumped	**Slight[a]**	**Moderate[b]**	**High[c]**
Fine-grained soils (LL > 50)[d] with medium to high plasticity (CH, MH, CH-MH)	No data available; consult a soils engineer or use E' = 0			
Fine-grained soils (LL < 50) with medium to no plasticity and less than 25% course-grained particles (CL, ML, ML-CL)	50	200	400	1000
Fine-grained soils (LL < 50) with medium to no plasticity and more than 25% course-grained particles (CL, ML, ML-CL) Course-grained soils with more than 12% fines (GM, GC, SM, SC)	100	400	1000	2000
Course-grained soils with less than 12% fines (GW, GP, SW, SP)	200	1000	2000	3000
Crushed rock	1000	3000	3000	3000

[a]Slight compaction = <85% Proctor, <40% relative density

[b]Moderate compaction = 85%-95% Proctor, 40%-70% relative density

[c]High compaction = >95% Proctor, >70% relative density

[d]LL = liquid limits

In certain situations, such as where existing soils have high plasticity, compacted granular backfill may be required to provide an adequate soil envelope around the pipe. In these situations the Soils Report will recommend granular material for backfill. Locations where compacted granular backfill is required should be noted on the plans.

Table 8.4-3 Design Data for CAP with 2-2/3 x 1/2 in. Corrugations, E' = 400 psi

Diameter (in.)	Minimum Cover* (in.)	Maximum Height of Fill* (ft)				
		Pipe Gauge				
		16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
12	12	38	46			
15	12	24	28			
18	12	17	20			
21	12	14	15			
24	12	12	13	15		
27	12		12	13		
30	12		11	12		
36	12		10	10	11	
42	12			10	10	
48	12			9	9	10
54	15			5	9	9
60	15				5	7
66	18					4
72	18					4

*Top of pipe to top of sub-grade

Table 8.4-4 Design Data for CAP with 2-2/3 x 1/2 in. Corrugations, E' = 750 psi

Diameter (in.)	Minimum Cover* (in.)	Maximum Height of Fill* (ft)				
		Pipe Gauge				
		16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
12	12	50	50			
15	12	37	42			
18	12	29	32			
21	12	25	27			
24	12	23	24	27		
27	12		22	24		
30	12		21	23		
36	12		20	21	22	
42	12			20	21	
48	12			20	20	20
54	15			17	19	20
60	15				17	19
66	18					16
72	18					12

*Top of pipe to top of sub-grade

Table 8.4-5 Design Data for CAP with 2-2/3 x 1/2 in. Corrugations, E' = 1500 psi

Diameter (in.)	Minimum Cover* (in.)	Maximum Height of Fill* (ft)				
		Pipe Gauge				
		16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
12	12	50	50			
15	12	50	50			
18	12	50	50			
21	12	50	50			
24	12	49	50	50		
27	12		49	50		
30	12		47	49		
36	12		46	47	48	
42	12			46	46	
48	12			45	45	46
54	15			45	45	45
60	15				45	45
66	18					45
72	18					44

*Top of pipe to top of sub-grade

Table 8.4-6 Design Data for CAP with 3 x 1 in. Corrugations, E' = 400 psi

Diameter (in.)	Minimum Cover* (in.)	Maximum Height of Fill* (ft)				
		Pipe Gauge				
		16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
30	12	17	19			
36	12	13	15			
42	12	12	12	14		
48	12	11	11	12	13	
54	15	10	10	11	12	
60	15	9	10	10	11	12
66	18	9	9	10	10	11
72	18	6	9	10	10	10
78	21		6	9	10	10
84	21			8	9	10
90	24				9	9
96	24				6	8
102	24					6
108	24					
114	24					
120	24					

*Top of pipe to top of sub-grade

Table 8.4-7 Design Data for CAP with 3 x 1 in. Corrugations, E' = 750 psi

Diameter (in.)	Minimum Cover* (in.)	Maximum Height of Fill* (ft)				
		Pipe Gauge				
		16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
30	12	28	31			
36	12	25	26			
42	12	22	23	25		
48	12	21	22	23	24	
54	15	20	21	22	23	
60	15	20	20	21	22	22
66	18	20	20	20	21	21
72	18	18	19	20	20	21
78	21		18	20	20	20
84	21			19	20	20
90	24			17	19	20
96	24			14	19	19
102	24				16	19
108	24				13	16
114	24					13
120	24					12

*Top of pipe to top of sub-grade

Table 8.4-8 Design Data for CAP with 3 x 1 in. Corrugations, E' = 1500 psi

Diameter (in.)	Minimum Cover* (in.)	Maximum Height of Fill* (ft)				
		Pipe Gauge				
		16 Gauge	14 Gauge	12 Gauge	10 Gauge	8 Gauge
30	12	50	50			
36	12	48	50			
42	12	41	50	50		
48	12	36	46	49	50	
54	15	32	40	48	49	
60	15	29	36	47	48	48
66	18	26	33	46	47	47
72	18	24	30	42	46	47
78	21		28	39	46	46
84	21			36	45	46
90	24			34	45	45
96	24			32	42	45
102	24				40	45
108	24				38	44
114	24					40
120	24					37

*Top of pipe to top of sub-grade

Table 8.4-9 Design Data for CAPA with 2-2/3 x 1/2 in. Corrugations

Span x Rise (in.)	Minimum Gauge	Minimum Cover (in.)	Maximum Height of Fill*(ft)
17 x 13	16	12	13
21 x 15	16	12	12
24 x 18	16	12	13
28 x 20	14	12	12
35 x 24	14	12	12
42 x 29	12	12	12
49 x 33	12	15	12
57 x 38	10	15	12
64 x 43	10	18	12
71 x 47	8	18	12

*For soil bearing capacity of 2 tons/ft^2 around corners of pipe

Table 8.4-10 Design Data for CAPA with 3 x 1 in. Corrugations

Span x Rise (in.)	Minimum Gauge	Minimum Cover (in.)	Maximum Height of Fill*(ft)
60 x 46	14	15	20
66 x 51	14	18	20
73 x 55	14	21	18
81 x 59	12	21	16
87 x 63	12	24	16
95 x 67	12	24	15
103 x 71	10	24	16
112 x 75	8	24	15

*For soil bearing capacity of 2 tons/ft^2 around corners of pipe

8.5 THERMOPLASTIC PIPE

Table 8.5-1 should be used to determine the maximum height of fill for thermoplastic pipes installed in embankments.

The minimum cover for thermoplastic pipes is as follows: 2.0 ft.

The minimum cover is measured from the top of the pipe to the bottom of the pavement or surface.

The maximum diameter for PEP is 60 inches.

The maximum diameter for PVCP is 36 inches.

Table 8.5-1 Thermoplastic Pipes (Maximum Fill Height (ft) for Sn-90)

Diameter (inches)	PEP	PVCP
12	15.5	21.5
15	15.0	19.5
18	16.0	18.0
21	15.5	18.5
24	15.5	17.5
30	15.0	16.5
36	14.0	15.5
42	13.5	N/A
48	13.0	N/A
*60	10.0	N/A

* Fill height for 60 inch PE is not a KDOT calculated value. It is based on information from the Plastic Pipe Institute and a survey of other State DOT’s.

Ground Water Table at Spring Line

Based on AASHTO Tables A12-11,12,13 in the AASHTO LRFD Bridge Design Specifications.

Minimum Fill Height = 2.0 ft.

8.6 REINFORCED CONCRETE BOXES

This section contains general information and procedures for the selection and design of RCB culverts. More detailed information on structural design and details of RCB culverts is presented in the Bridge Design Manual.

Standard drawing sheets for RCB details may be obtained through the Kansas Automated RCB System. Plan detail sheets, quantities and cost estimates and can be generated for one-cell, two-cell and three-cell RCB culverts with cell spans from 3.0 ft to 20.0 ft. These quantities and plan detail sheets include wingwalls and aprons.

For gathering comparison information and/or estimating purposes regarding RCB size and design type (fixed or pinned) selection, external designers should log in to the KART System (http://kart.ksdot.org), open the RCB Form, and enter the required data in the KDOT Standard RCB/RFB Detail Request Application. This procedure replaces the previous RCB request form in PDF format. The request application provides the following benefits:

- It validates the input entered
- It limits requests to available box standards drawings
- It calculates an online quantity/detail/cost summary before submitting to KDOT for creation of a CADD file in Microstation format (dgn), alternative RCB sizes may be run before final details are requested.
- It creates the input file used with the internal windows RCB program for submittal to the appropriate KDOT Section by e-mail.

When RCB size has been selected, external designers may obtain RCB details by submitting a “Standard RCB/RFB Detail Request Application” electronically to the appropriate KDOT unit within the Division of Engineering and Design.

The designer should pay particular attention to the following points:

1. The type of structure (pinned or fixed) should be specified. (See the Bridge Design Manual).

2. The height of fill should be specified. Arbitrarily adding fill height will not necessarily result in a stronger RCB.

3. A pre-cast RCB should be allowed as an option to a cast-in-place box unless conditions preclude its use. If cast-in-place construction is required, this restriction should be stated in the plan notes.

4. A culvert with a total span (as defined in the Bridge Design Manual) longer than 20.0 ft is classified as a bridge. Bridge structures are the responsibility of the State Bridge Office, and should be assigned a bridge serial number and designed in accordance with the requirements in of the Bureau of Structures and Geotechnical Services.

5. A culvert with a total span of 10.0 ft to 20.0 ft is classified as a 10'-20' structure and is assigned a culvert serial number by the KDOT Bridge Management Section. The serial number should be requested prior to final plans.

8.7 REFERENCES

American Concrete Pipe Association (2000). *Concrete Pipe Design Manual*.

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American Iron and Steel Institute (1994), *Handbook of Steel Drainage and Highway Construction Products*, 5th edition.

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